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HANNA HEIKKILÄ (ed.)

FINNISH-KARELIAN SYMPOSIUM ON MIRE CONSERVATION AND CLASSIFICATION

NATIONAL BOARD OF WATERS AND THE ENVIRONMENT
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Cover photo: Finnish-Karelian mire research expedition on Lishka
Moh mire in Vodlozerski national park, Karelia
Photo: Raimo Heikkilä

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Abstract
This publication is a colletion of papers based on presentations in a Finnish–karelischen symposium on the classification and conservation of mires, held in 1992. The symposium was arranged according to the contract of cooperation between the ministries of environment of Finland and Karelia, about mire conservation research. The aim of the cooperation is to improve the conservation of mires in the biogeographically uniform area of Eastern Fennoscandia, taking into account the great differences in mire utilization in Finland and Karelia. Another aim is to develop and unify the research methods.

Paludification and development of mires is treated in three papers. Lake terrestrialization in Finland has been studied. Mires in fault valleys on the northwestern side of Lake Onega in Karelia have interesting stratigraphical features. The nutrient status of mires at different stages of development has been studied in Karelia, and the usability of the method is studied.

The annual growth of hummock and lawn layer *Sphagna* and its dependence on the weather of the growth period has been studied in Karelia. The relationships of carbon balance, growth and different forms of mire utilization in Finland have been studied. The vegetation of the mires in Vodlozersky national park in Karelia has been studied in Finnish–Karelian cooperation. The main features of the vegetation are presented in one paper.

Four articles deal with mire conservation. Threatened mire plants and their conservation are treated in one paper. Another deals with the present state of mires in the raised bog zone in Finland, and the success of mire conservation. Gaps in mire conservation and possibilities to improve the protection of mires in Finland have been studied. As an example of restoration of drained mires in nature reserves, information is given about the Seitseminen national park in Finland.

Eight scientists from Finland and six from Karelia took part in the symposium. In connection with it, an excursion to Lakkasuo and Siikaneva mire reserves was arranged. These mires and their research is presented in one article.

Keywords
Finnish–Karelian cooperation, mire, classification, mire protection, Finland, Karelia

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Tiivistelmä

Julkaisu koostuu vuonna 1992 pidetyn suomalais-karjalaisen symposion esitelmistä. Aiheena oli soiden luokittelu ja suojelu. Symposio järjestettiin Suomen ja Karjalan ympäristöministeriöiden soidensuojelututkimusta koskevan yhteistyösopimuksen mukaisesti. Yhteistyön tavoite on soiden luokittelun ja suojelun kehittäminen luonnonmaantieteellisesti yhtenäisellä Itä-Fennoskandian alueella ottaen huomioon soiden käytön suuret erot Suomessa ja Karjalassa. Tavoitteena on myös tutkimusmenetelmien yhteensovittaminen ja kehittäminen. Symposio pidettiin 12.-16.10.1992 Helsingin yliopiston metsäasemalla Hyytiälässä.

Soiden syntyä ja kehitystä käsitellään kolmessa esitelmässä. Suomen oloissa on tutkittu järvien umpeenkasvua soistumistapana. Äänisen luoteispuolella siirroslaaksoissa sijaitsevien paksuturpeisten soiden stratigrafiassa on mielenkiintoisia erityispiirteitä. Karjalassa on tutkittu turpeen kasvijäänteiden avulla suon ravinteisuutta kehityksen eri vaiheissa, ja menetelmän käyttökelpoisuutta selvitetään kolmannessa esitelmässä.

Mätäs- ja välipinnan rahkasammalten vuotuista kasvua ja sen riippuvuutta kasvukauden säästä on tutkittu Karjalassa. Soiden hiilitaseen, kasvun ja eri käyttömuotojen suhdetta Suomen oloissa pohditaan yhdessä esitelmässä.

Karjalan Vodlajärven kansallispuiston soiden kasvillisuutta on tutkittu suomalais-karjalaisena yhteistyönä. Alueen kasvillisuustyypit pääpiirteissään esitellään yhdessä esitelmässä.

Neljä esitelmää liittyy soidensuojeluun. Yhdessä pohditaan Itä-Fennoskandian suokasvien uhanalaisuutta ja suojelutilannetta. Yksi esitelmä esittelee soiden nykytilaa keidassuovyöhykkeessä Suomessa ja siihen liittyen soidensuojelun onnistumista. Soidensuojelun puutteita ja soidensuojelun täydentämistä Suomessa käsitellään yhdessä esitelmässä. Soiden ennallistamisesta suojelualueilla esitellään esimerkkinä Suomesta Seitsemisen kansallispuisto.

Symposioon otti osaa kahdeksan tutkijaa Suomesta ja kuusi Karjalasta, ja siihen liittyi retkeily Lakkasuon ja Siikanevan suojelualueille.

Asiasanat (avainsanat)
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Publikationen innehåller föredragen från finsk-karelska symposiet som ägde rum vid Helsingfors universitets fältstation i Hyytiälä 1992. Temat för symposiet var myrars klassifikation och skydd. Symposiet anordnades som en del av samarbetsavtalet inom myrskyddsforskningen mellan finlands och karelens miljöministerier. Målsättningen med samarbetsprojektet är utvecklandet av myrklassifikationen och skyddet av myrarna inom det växtgeografiskt enhetliga östra Fennoskandien med hänsyn taget till skillnaderna i myranvändningen i Finland och Karelen. Dessutom var målsättningen att jämka samman och utveckla existerande forskningsmetoder.

Tre presentationer behandlade myrars bildning och utveckling. Ett av föredragen behandlade igenväxningen av sjöar som ett exempel på myrbildning i Finland. I andra föredraget beskrevs särdragen i myrarnas stratigrafi i torvossor belägna i en förkastningsdal nordväst om Äänínen. I tredje föredraget presenterades resultat från undersökningar i Karelen var man med hjälp av växtfragment från torven har kartlagt myrens näringstillgång inom dess olika utvecklingsfaser samt redovisas metodens användbarhet.

Årliga tillväxten av vitmosse tuvor och höljor och deras relation till klimatet under tillväxtperioden har undersökts i Karelen. Myrarnas kolbalans, tillväxt och olika användningsformers relationer i Finland behandlas i ett föredrag.

Vegetationen har undersökts inom Vodlajärvi nationalpark i Karelen inom ett finsk-karelskt samarbetsprojekt. Huvuddragen av områdets vegetationstyper presenteras i ett föredrag.

Fyra föredrag behandlar skyddet av myrar. Ett föredrag behandlar myrväxternas hotstatus och skyddet av hotade myrväxter i östra Fennoskandien. Ett föredrag behandlar myrarnas tillstånd och myrskyddets framgång inom högmosseregionen. Ett föredrag beskriver bristerna i myrskyddsprogrammet samt hur myrskyddet bör kompletteras. Som exempel på ett finskt restaureringsprojekt inom ett myrskyddsområde presenteras resutat från restaureringsprojektet inom Seitseminen nationalpark.

Vid symposiet deltog 8 forskare från Finland och 6 forskare från Karelen. Till symposiet hörde en exkursion till naturskyddsområdena Lakkasuo och Siikaneva.

Sakord (nyckelord)
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Zusammenfassung
Der Inhalt dieser Veröffenlichung besteht aus Vorlesungen aus dem finnisch–karelischen Symposium, welches 1992 in der Waldstation der Universität Helsinki, in Hyytiälä, veranstaltet wurde. Das Thema des Symposiums war die Klassifizierung von Mooren und deren Schutzmassnahmen.

Die Entstehung und Entwicklung von Mooren wird in drei Vorlesungen behandelt. Eine dieser Vorlesung erklärt die Bedeutung von dem Zuwachsen der Seen in Umständen, die in Finnland herrschen. Die zweite Vorlesung stellt die stratigraphischen Besonderheiten der Moore in den Versetzungstäler nordwestlich des Onega Sees vor. In Karelien hat man mit Hilfe der vorhandene Pflanzenreste im Torf, den Nährstoffgehalt des Moores während der verschiedenen Entwicklungsstufen erforscht. Die dritte Vorlesung erlärt die Anwendungsfähigkeit dieses Verfahrens.

Die Flora des karelischen Nationalparks Vodlozero wurde in finnisch–karelischer Kooperation erforscht. Die Pflanzentypen dieses Gebietes werden hauptsächlich in einer Vorlesung vorgestellt. Das jährliche Wachstum sowie dessen Abhängigkeit von den Witterungseinflüssen während der Wachstumpsperiode der Torfmoore in der zwischenschicht und in den Torfhügeln wurde in Karelien erforscht. In einer Vorlesung wird über den Kohlenstoffgehalt, das Wachstum sowie über Nutzungsmassnahmen unter finnischen Bedingungen nachgedacht.

Vier Vorlesungen befassen sich mit Schutzmassnahmen. Gemeinsam wird über die Bedrohung der Moorflora und den derzeitigen Schutmassnahmen in Ost Fennoskandinavien nachgedacht. Eine Vorlesung befasst sicht mit dem derzeitigen Zustand der Moore in dem finnischen Hochmoorstreifen und dem gelingen der Moorschutzmassnahmen. Fehlende Schutzmassnahmen und Vervollständigung der Moorschutzmassnahmen werden in einer weiteren Vorlesung behandelt. Als Beispiel der Rekultivierung von Schutzgebieten wir der Nationalpark Seitseminen vorgestellt. Als letztes werden die Wanderstrecken des Symposiums und die dazu gehörenden Forschungen vorgestellt.

Stichwörter
finnisch–karelische Zusammenarbeit, Moor, Klassifizierung, Moorschutz, Finnland, Karelien

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Резюме
Настоящая публикация состоит из докладов финско-карельского симпозиума, организованного в Хюютияля, на станции лесоведения Хельсинкского университета в 1992 году. Темой симпозиума была классификация и охрана болот.

Возникновение и развитие болот обсуждают в трех докладах. Один из них выясняет значение зарастания озер в условиях Финляндии. В другом докладе рассматривается специальные черты стратиграфии болот, находящихся в котловинах на северо-западной стороне Онежского озера. В Карелии изучали питательность болота на разных стадиях развития с помощью разложения растении в торфяной почве. Годность этого метода выясняется в третьем докладе.

Растительный покров болот Карельского Водлозерского национального парка исследовали совместно финские и российские специалисты. Типы растительности в основном выясняются в одном докладе.

В Карелии изучали годовой прирост сфагновых мхов на разных поверхностях болота и его зависимость от погоды вегетационного периода.

В одном докладе обсуждается связь между угольным балансом, приростом и разными способами использования болот в условиях Финдяндии.

В публикации четыре доклада связаны с охраной болот. В одном докладе обсуждается исчесновение болотных растений и положение охраны в Восточной Фенноскандии. Один доклад показывает состояние болот на данный момент на зоне верхних болот в Финляндии и, в связяно с ним, успехи в охране болот. Недостатки охраны болот и пополнение охраны рассматривается в одном докладе. Примером восстановления болот на охраняемой территории показывается национальный парк Сейтсеминен.

В конце публикции рассказывается о предметах экскурсий симпозиума и об исследований связаны с ними.

Ключевые слова
Финско-карельское сотрудничество, болото, классификация, охрана болот, Финляндия, Карелия

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LAKE TERRESTRIALIZATION AS A MODE OF MIRE FORMATION - A REGIONAL REVIEW

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1 Introduction

Lakes are usually not permanent elements in the landscape but exist for only a short period. As time passes, accumulation of bottom sediment and deepening of the outlet channel will ultimately cause a basin to become shallower. Plants colonize the shallow margins and speed up the filling process, so that the whole basin may finally become occupied by a swamp or a fen community. The limnic deposits to be found at the bottoms of many present-day mires suggest that innumerable lakes in Scandinavia alone have disappeared from the landscape in this way during postglacial times (Tikkanen 1990). Terrestrialization thus forms an integral part of the natural life-span of lake basins.

In spite of the marked role of the lake terrestrialization processes in shaping the local landscape, surprisingly little interest has been shown among ecologists in hydroseral successions as such. Many fundamental questions are unresolved or subject to numerous contradictory explanations. Why do certain lakes develop into mires while others don't? Has lake filling-in proceeded in a gradual, uninterrupted manner, or have there been substantial perturbations within the development? And the most decisive question of all as far as interpretation is considered: is the hydroseral succession from open water to mire dependent chiefly on factors external or internal to the ecosystem?

Because of the long time taken for hydroseral changes to occur (Spence 1964), direct observations of hydrosere dynamics are difficult. It is here that a palaeoecological approach is of great help. The present work seeks to answer at least some of the above stated questions by examining available post-glacial stratigraphic information of hydroseral successions in Finland. Before embarking on this, however, the concept of a hydrosere should first be discussed at a more general level.

2 Theoretical hydrosere and its testing

The standard ecological concept of a hydrosere is that originally described by Clements (1916) but is perhaps most succinctly stated by Tansley (1939) and illustrated Fig. 1. According to this typology, the ordinary sequence during the filling in of a basin, the hydrosere, passes through the stages: limnic sediment - telmatic peat - terrestric (wood) peat. The above sequence is always recognizable if the filling in has proceeded

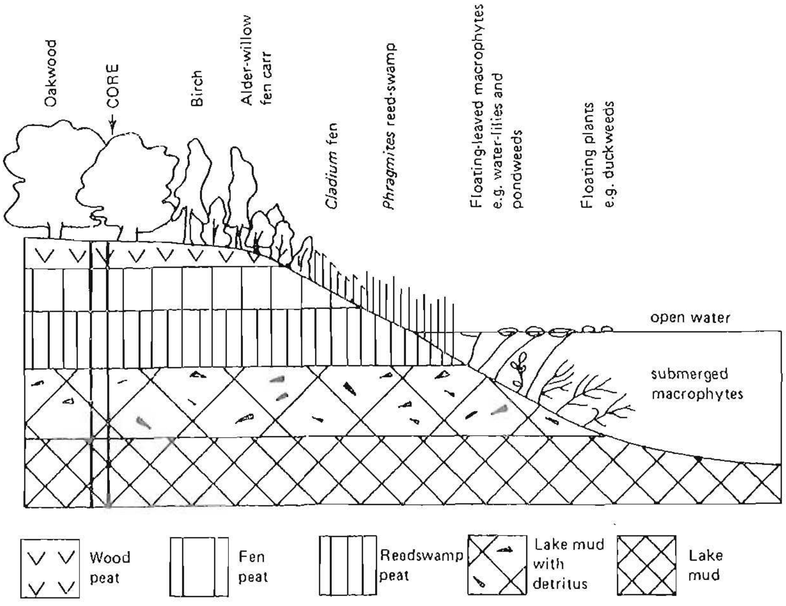

Fig. 1. Theoretical hydrosere, and the sediments produced by each vegetational stage (after Birks & Birks 1980)

normally, although the specific types of sediment and peat may differ according to the chemical and physical conditions under which they have been formed.

The main factor controlling the progression of the hydrosere is the height of the water table. As a lake becomes shallower, islands of vegetation emerge on its shores, and these then gradually increase in area until they eventually fuse together. When the process has been going on sufficiently long, the remaining stretches of open water become filled first with submerged plants, then floating-leaved aquatic plants and finally reedswamp species and other helophytes.

As the reedswamp peat accumulates, fen plants colonize it followed by drier shrub species forming a fen carr. After the lake has completely filled with organic debris, plants and trees may finally take over. In Tansley's scheme it is the oakwood that constitutes the climax stage of nearly all hydroseres within the suboceanic climate system. As he writes: "the hydrosere, as it is called, beginning in water, culminates, like the xerosere, in the establishment of climax forest" (Tansley 1939: 114).

Tansley's theory of hydroseral development was tested under field conditions by Walker (1970). He studied the successional pathways in 159 British hydroseres using pollen-analytical and sediment stratigraphical data. Walker was able to recognize 12 different phytosociological units or hydroseral stages, which he arranged in order 1 to 12 in ascending order, from open water to oakwood or bog (Fig. 2). As pointed out by Faegri & Iversen (1989), however, some of Walker's categories are hydrologically ambiguous ('aquatic *Sphagna*', 'marsh'). Nevertheless, Walker's merit was to reveal the variety of sequences of plant communities which can occur during the overgrowth of lakes. There is no single preferred successional pathway apart from the over-all reduction of open water, though the majority of sequences involve a reed-swamp stage during the development towards the 'climax' state.

Perhaps even more to Walker's credit than showing the diversity of successional pathways was his demonstration that it is the bog that is the natural 'climax' of

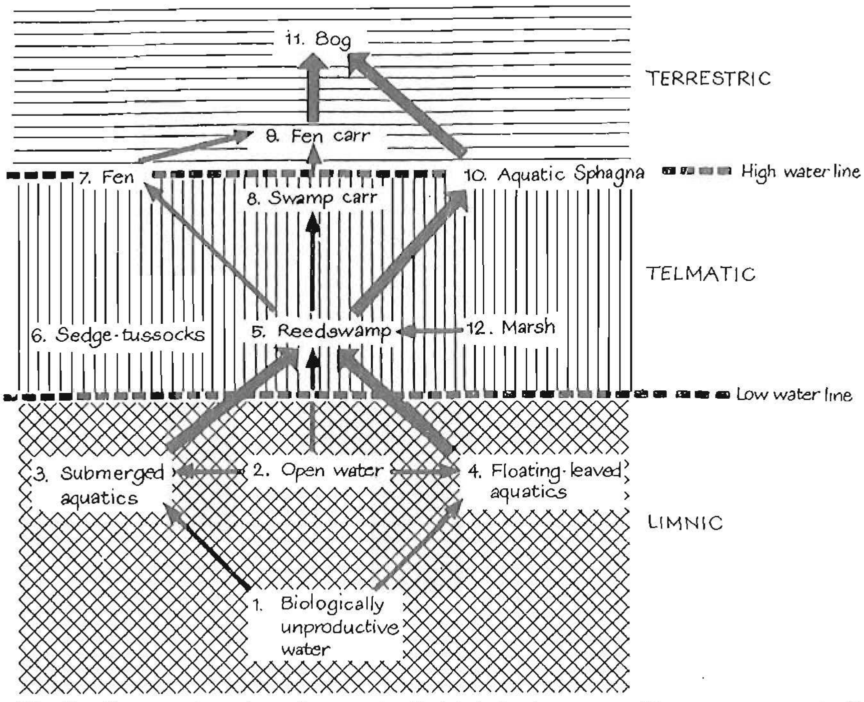

Fig.2. Successional pathways in British hydroseres. Heavy arrows indicate the main pathways (original data according to Walker 1970, modified by Faegri & Iversen 1989).

autogenic hydroseres throughout the British Isles. The transition from fen to oakwood was thus unsubstantiated. In fact, it is likely that such is the case almost throughout the northern hemisphere, and forest delevopment can be seen as a rather unusual climax for a hydrosere (see e.g. Godwin & Turner 1933).

3 Finnish hydroseres and their role in mire formation

In Finnish context, two or sometimes three special kinds of terrestrialization are normally distinguished. Perhaps the most frequent one sets out from the lake bottom, where helophytes and floating-leaved plants expand vegetatively (Fig. 3a). In this case the terrestrialization sequence starts with the establishment of a zone of reed swamp around the lake and terminates with these marginal helophytes (e.g. *Phragmites australis*, *Schoenoplectus lacustris*, *Equisetum fluviatile*) spreading over the whole water body. The succession is a self-feeding process, in which increasing plant mass means accelerated sedimentation. This type of succession is usually considered as being common in shallow, nutrient-rich basins, although some recent investigations indicate that it may be frequent in ultra-oligotrophic and relatively steep lakes as well (Korhola 1992a).

The alternative process sets out from the lake surface, where certain plants, notably *Sphagnum* mosses, produce a sort of floating mat which develops horizontally, reducing the open water area (Fig. 3b). This mode of overgrowth is typical of small, oligotrophic and relatively steep basins and is normally a slow process, although very few minutely examined examples of such succession can be found in the existing literature.

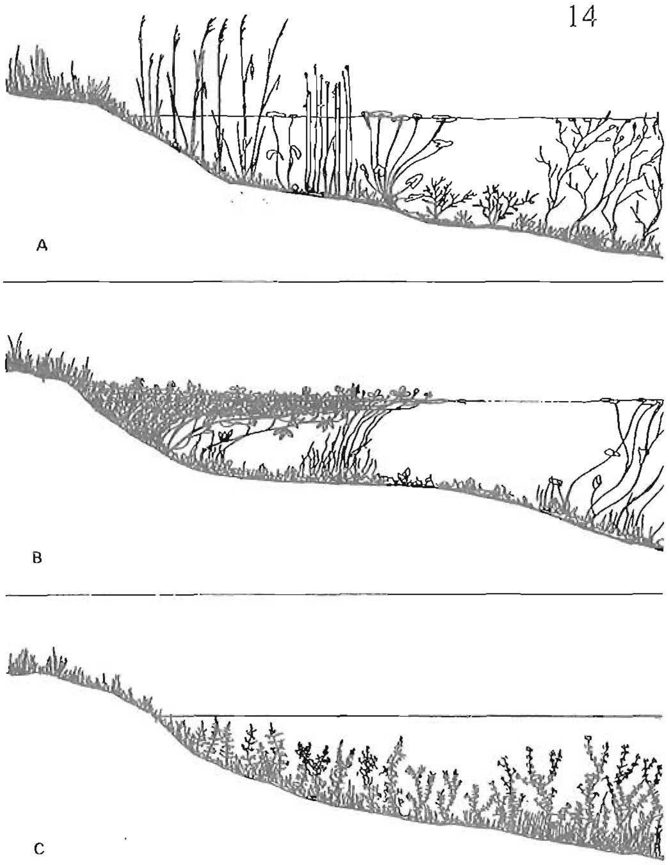

Fig. 3. The main modes of filling-in: a) along bottom, b) along surface, c) intra-aquatic (after Hellsten & Nybom 1990).

Some authors (e.g. Hellsten & Nybom 1990) distinguish also a third mode of terrestrialization, an 'intra-aquatic' filling in, where the process is initiated and maintained by submerged plants, which are loosely or not at all fastened to the lake bottom (Fig. 3c). This type of succession is common in lakes with a high humus content, the typical plants associated with it including e.g. *Potamogeton* spp., *Myriophyllum* spp.

It is not always easy to distinguish between these different modes, at least in palaeoecological recostructions, because the processes may advance simultaneously in one and the same lake.

Traditionally the role of the filling-in of water bodies in the formation of the Finnish peatlands is considered to be relatively minor. The estimates repeatedly given in the literature for the proportion of terrestrialization in the origin of the total Finnish mire area constitute between 5 to 10%, with higher figures to be found in the old inland areas and lower in the younger coastal soils (Huikari 1956; Tolonen 1983). Recently this standpoint has been questioned, however, by Korhola (1990b), according to whom the percentages should be much higher especially for the wide area of the southern raised bogs.

This conclusion is already justified on the basis of Fig. 4, which shows the areally-weighted occurrence of the limnic sediments (gyttja) at the bottoms of the Finnish mires. According to this, the filling in of the water bodies has been markedly more frequent in the southern part of the country than stated by the previous estimates, the correct percentages being 20% or so and in some regions over 40% of the present mire area. The likelihood that even these figures are most probably still too low, becomes clear when keeping in mind the fact that mud in lakes does not normally occur over the erosion zone (Håkanson 1977).

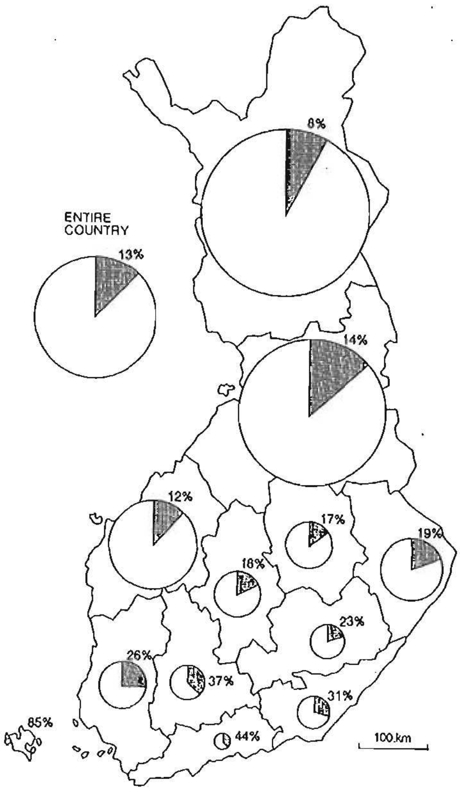

Fig. 4. The occurrence of gyttja at the bottom of the investigated mires (649 000 hectares) in Finland (after Lappalainen & Toivonen 1985, redrawn by Korhola 1990b).

The significance of terrestrialization in the origin of the mires in Finland becomes even more evident if the areal dimensions are left out of consideration. Already a rapid look at the available peat-stratigraphical data from southern Finland (e.g. Aartolahti 1965; Tolonen 1967; Korhola 1990b; 1992b) reveals the fact that almost regularly the oldest parts of the investigated mires are situated on gyttja bottoms. This means that, although limited in extent, the filling-in of small water bodies has played a crucial role in the induction of the initial peat accumulation and the subsequent spread of the peat over wide ares. This has led Korhola (1990b) to use the expression 'the prime mover' when speaking of the role of overgrowth in the formation of peatlands in southern Finland.

4 The rate of lake terrestrialization process

The hydroseral process is usually considered as being slow by comparison with authogenic terrestrial ecological changes of similar magnitude (Walker 1970). One reason for this is that the overgrowth of open water by swamp plants must await the time when accumulated bottom deposits have made the water shallow enough, that bottom rooting phanerogams can live in it. The rate of sediment accumulation is affected by several factors - in addition to the simple time aspect - like the trophic conditions of the lake itself and its catchment area, the area and the shape of the lake and the topography of its bottom and its surroundings (Frenzel 1983).

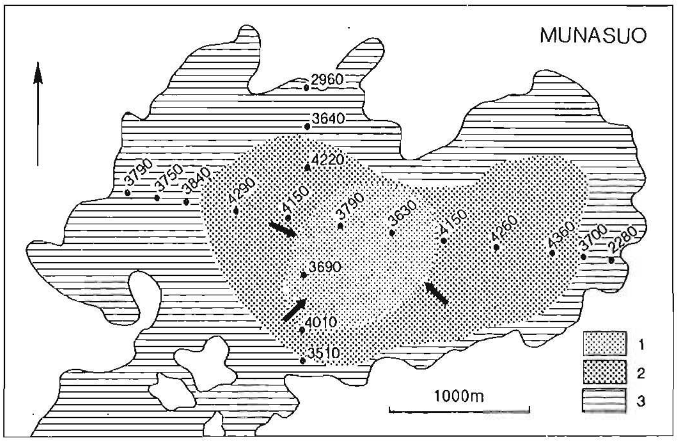

Fig. 5. Basal peat radiocarbon dates from the raised bog of Munasuo, in Pyhtää.
1 – The filling-in centre, quagmired approx. 4000 - 3600 BP.
2 – Littoral zone of the ancient lake, quagmired approx. 4300 - 4000 BP.
3 – Area of lateral mire expansion, paludified approx. 4000 - 2200 BP.
Dotted areas show the distribution of gyttja at the bottom of the mire (after Korhola 1992b).

Natural rates of hydroseral change can be inferred, at least in theory, from stratigraphic sequences, provided that reliable datings for particular levels in a profile are known. Tallis (1983) compiled data for rates of accumulation of a number of different types of organic sediments from different areas, and was able to determine a mean accumulation rate of c. 6.0 cm per century, both for different sediment types and for different countries, with the total range of recorded variation from 1.3 cm per century to 55.3 cm per century. The data clearly indicate that the rates of change relative to the human life span are slow, and according to Walker (1970), for instance, the reedswamp, although amongst the most short-lived of hydroseral stages, may commonly persist for 500 years.

The main problem associated with the above mentioned accumulation rates is that the original data is normally derived from only a single vertical core taken from the deepest point of the present fen or bog, and then extrapolated to cover the whole mire area. As is commonly known, however, the rates of hydroseral change may not be the same in all parts of a basin, the differences being caused for instance by differences in degree of silt accumulation and/or in general land-use (Pigott & Wilson 1978). In such cases, a core from under the bog or fen does not automatically produce a sequence of sediments laid down in time which is the same as the sequence being laid down in space, as proposed by the original theory of a hydrosere (Tansley 1939; Fig. 1).

To avoid such problems Korhola (1992b) used a method of systematic basal peat radiocarbon datings in analyzing the hydrosere dynamics in time and space. Fig. 5 shows the dates (without standard deviations) for the basal peat in Munasuo, which is one of the largest (673 ha) raised bogs in a natural condition anywhere in southern Finland, being located in the commune of Pyhtää in southeastern Finland. Its peat depth is 6.8 m at a maximum, and over 6 m throughout the central plateau. In the middle part of the mire basin the peat deposit has accumulated on top of a gyttja horizon, which on the basis of its diatom and macrosubfossil content is of lacustrine origin (Korhola 1992b). By contrast, the marginal peats have accumulated directly on clay or till.

As shown by Fig. 5, the ages of the basal peat fall relatively close together in time, with the oldest of all appearing at the edges of the central plateau, following fairly accurately the outer limit of the gyttja occurring at the base of the mire. It would thus seem that mire formation began in the littoral zone of the ancient lake and advanced towards the centre of the lake, in which direction the dates become systematically younger. This process of infilling began around 4 300 BP and came to an end around 3 600 BP, so that the whole ancient lake basin of c. 312 ha in size may be said to have become overgrown in the course of some 600 radiocarbon years. The mean rate of horizontal advance of the marginal vegetation was initially (4 360 -4 150 BP) about 2.3 - 3.5 m a^{-1}, slowing down later (4 150 - 3 630 BP) to about 0.6 - 0.9 m a^{-1}. Especially rapid rates were shown for *Phragmites*-dominated plant communities (Korhola & Seppä in prep.). This species is particularly quick to invade new sites, being known as an efficient biomass producer.

The rapidity of the hydroseral change documented in Munasuo is in harmony with other stratigraphic data so far available by the author. For instance, in Kotasuo, which today is a small raised bog situated in the municipality of Espoo, near Helsinki, the final terrestrialization of an ancient, c. 12 ha lake was documented as having occurred within some 20-30 years according to the radiocarbon datings (Korhola 1990a). The rapidity of the succession was indicated by sudden changes in the composition of the cladoceran and diatom assemblages as well as in the macrosubfossil and pollen records. The reedswamp stage was also short in duration at this particular site, having lasted some 200 years or so.

The rapid nature of a hydroseral change as described above is understandable also on the basis of certain current evidence, where a 2-3 metre advance of reed species toward the lake centre during one vegetation period is reported to have occured in some lakes under certain circumstances (Anttonen-Heikkilä 1983). The results are also consistent with the cartographic source data from the United States, which indicate a rapid proceeding of many hydroseres during the last century or so (e.g. Gates 1942). In addition, there is no doubt that hydroseral changes can proceed rapidly following artifically induced changes. One might perhaps conclude, that generally taken the terrestrialization can be regarded as a slow process, but it may be speeded up in certain
extreme circumstances. Next a closer look will be taken at such perturbation situtations.

5 Autogenic or allogenic process?

The lake terrestrialization process has traditionally been considered as a parade example of a linear autogenic succession, in which the plants themselves initiate changes in the land surface that consequently cause vegetational changes (e.g. De Blij & Muller 1993). The overgrowth, at least in the early stages, is essentially a topographic process of mire formation, so that much of the stratigraphy of such mires can be ascribed to definable events other than climate (Frenzel 1983). As stated by Walker (1970): "The study of autogenic hydroseres is therefore inherently unpromising as a source of information about climatic fluctuations".

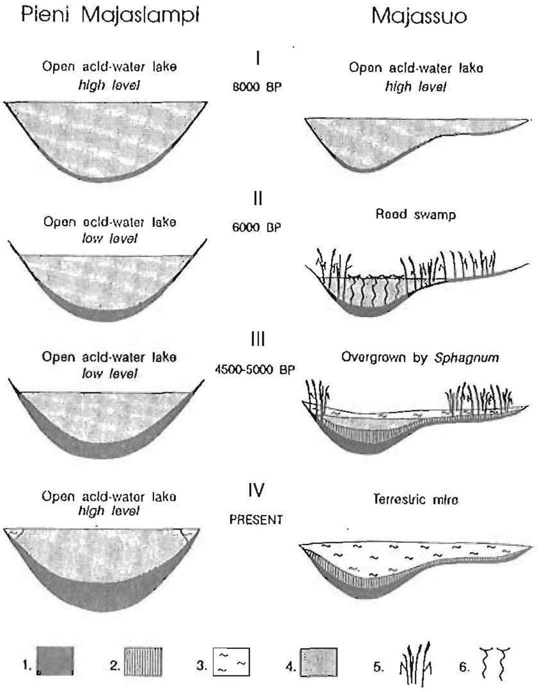

Fig. 6. Main successional stages in two neighbouring rocky basins in southern Finland.
1 – Gyttja.
2 – telmatic peat.
3 – peat.
4 – water.
5 – helophytes.
6 – floating-leaved plants.
(after Tikkanen & Korhola 1993).

On the other hand a revision of the hydroseral sequence, if it occurs, indicates that the regular hydrosere has been interrupted. Such inverted sequences are best attributed to some environmental change, which may well be a result of climatic changes taking effect in the catchment of the basin (Walker 1970). According to this way of thinking the proceeding of the hydroseres must have been regulated throughout their existence by autochtonous dynamic processes, with the involment of allochtonous factors restricted at most to a momentary disturbance. But can we really categorically exclude allochtonous factors such as climatic changes when deducing ancient hydroseres and their causes?

To answer this question Tikkanen & Korhola (1993) studied more closely the developmental history of two neighbouring hilltop basins, of which one, Pieni Majaslampi, has been a lake throughout its existence, but the other, Majassuo, was only initially a lake and was later overgrown, being at present a small ombrotrophic bog. The basins are of about the same age and size having been subjected to similar external circumstances. The main successional stages of these two basins, as deduced from the sedimentological and bistratigraphical data, are shown in Fig. 6.

Both basins must originally have been filled entirely with water up to their present threshold levels, as demonstrated by the occurence of gyttja also in the shallow bays of the present Majassuo basin (Tikkanen & Korhola 1993: 10). According to the criteria established by Korhola (1992b) for the identification of the 'first peat', the Majassuo basin became overgrown and was transformed into a terrestrial mire approx. 5 000 radiocarbon years BP. Before this the two lake basins had a very similar limnological history, as shown by diatom and *Cladocera* assemblages, both having begun as acidic, oligotrophic lakes with no macrophytic vegetation on their shores. Thus the overgrowing of the Majassuo basin cannot be connected to any difference in water quality.

Neither can the filling in of Majassuo basin have been caused merely by sediment deposition, since on the basis of the sediment accumulation rate prior to infilling the basin would still have been occupied by about two metres of water even today. In practise, however, it filled in and developed into a mire nearly 5 000 years ago, when there should still have been a lake of depth 3.60 m at the site. The only remaining alternative is that the terrestrialization must be related to some hydrological difference between the basins.

The bottom of the Majassuo basin is characterized by a telmatic *Phragmites* peat, which reaches a thickness of 85 cm at the deepest point (Fig. 6). Since this horizon lies at a depth of 470-485 cm in the deepest parts of the basin, it is impossible for a Phragmites vegetation to have been growing at the site under conditions in which the water level would have stayed at its originally high position (cf. Kulczynski 1949). The only possibility, then, is that at the time when the *Phragmites* peat was formed the water level must have been well below the threshold of the basin. The most plausible explanation for this is a climatically induced drop in water level, caused by a change in temperature or precipitation, or both. The reason that this event did not affect the adjacent Pieni Majaslampi basin lies in the slightly greater depth of the basin and the steepness of its sides (Tikkanen & Korhola 1993).

The above described development is not unique; similar successions seem to have taken place synchronically also elsewhere in southern Finland (see e.g. Valovirta 1965; Tynni 1966; Korhola 1990a + unpublished material). Commonly no appreciable advance in the filling-in processes is observed during the Boreal Chronozone or the beginning of the Atlantic, at a time when high water levels are presumed to have prevailed in lakes of southern Sweden and Finland (Alhonen 1970; Digerfeldt 1988). On the other hand, a marked advance in the hydroseres took place towards the end of the Atlantic Chronozone and at the beginning of the Subboreal, when low water levels are reported from southern Finland and Sweden (Alhonen 1970; Digerfeldt 1988). If the above described pattern holds true on a larger scale then the old idea of an autogenic, self-perpetuating nature of hydroseral succession is no longer universally valid. On the contrary, the hydroseres may in the future become an important source of information when trying to increase knowledge of past climatic fluctuations, especially changes in humidity. However, much additional work is needed in order to better understand the mechanism of hydroseral change.

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MIRES IN THE DENUTATION-TECTONIC RELIEF OF THE NW SHORE OF LAKE ONEGA. GENESIS AND STRATIGRAPHY.

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1 Introduction

The investigations of mires in the denudation-tectonic relief have been carried out in the north-western coastal part of Lake Onega (Fig. 1) within a large geological structure, so-called Onezhskaya Superimposed Trouph (Biske et al. 1971). It has been broken up into blocks of the north-western direction (340°) by series of tectonic saults. In the relief the saults look like as linear ravines or narrow stretched kettles. Nowadays these depressions are occupied by the bays of Lake Onega, numerous small lakes or mires. The length of the mires varies from 1 to 7 km and the width from 100 to 800 metres.

Simultaneous paleolimnological, palynological and radiocarbon analyses of lacustrine sediments (clays and sapropels) under mire peat deposits and numerous geological data have revealed that the genesis and the early stages of mire formation are closely connected with both the trans-regressive activity of Lake Onega in the Holocene and local new tectonic processes in bedrocks. The mires developed as a result of overgrowing of Lake Onega's shallow bays and small relict lakes separated from the main water body.

The modern vegetation of the mires studied is mainly presented by mesotrophic-eutrophic and eutrophic plant communities. Marginal parts of the mires are generally occupied by wood-herb-(reed)-*Sphagnum* or wood-sedge phytocoenoses, and herb-*Hypnum* or herb-*Sphagnum* communities and their complexes are widespread in central parts. The diversity and richness of the plant cover as well as the floristic composition are related to a favourable water-mineral regime. It is provided with both highly mineralized underground waters and surface waters rich in mineral substances, which flow down the slopes of ridges composed by Proterozoic basic or calcareous bedrocks and (Kuznetsov et al.1991).

All the mires studied are characterized by the eutrophic peat deposit type that is an evidence for permanent eutrophic water-mineral nutrient conditions in mire depressions, at all the phases of mire formation from the limnotelmatic contact horizon.The thickness of peat deposits in the genetic centres varies from 3 to 9 metres. There is a very wide spectrum of peat types in the composition of the peat deposits (Shevelin P., 1988, 1991).

2 Methods

Four mires in the denudation-tectonic relief were studied. Cross and longitidunal stratigraphic profiles were made through the genetic centres and marginal parts of the mires. Levelling of mire surfaces, peat deposit sounding (at intervals of 50 m) and distinguishing of facies (mire sites) were carried out along the profiles. Geobotanical descriptions of plant cover were made at all the facies distinguished. Cover percentage (%) and abundance (5-marks scale) have been estimated for each plant species throughout every studied mire site. Boreholes were made in genetic centres and at dominant mire sites. Peat, sapropel and clay samples were taken using a Russian peat sampler. The samples were analysed using macrofossil and palynological methods in the laboratory. The absolute age of sediments was determined using C_{14} dating.

3 Results

Rudnoe mire (30 ha) and Beryosovoe mire (26 ha) are situated on the territory of the State Natural Reserve "Kivatch" (Fig. 1). Both mires are of limnic genesis, they have been formed at the places of the remaining postglacial small lakes. Their peat deposits are underlain by lacustrine clays (Fig. 2, 3). They were accumulated from The Alleröd to the early Boreal (Bo) period (12 000-9 000 y.a.) on the bottom of the relict lakes. The rate of clay sedimentation was calculated to be 1.7-2.7 mm/year. The accumulation of sapropels began from the middle of the Bo-period when the lakes became more shallow and heated (8 680±60 y.a., Tartu -1 506; 8 130±120 y.a, Tartu -1 942). The beginning of paludification has been dated to the end of the Bo-time. The sapropel band deposited in the kettle of Beryosovoe mire is 1-1.5 m thick. The thin layers of reed and birch peats were formed in the late of Bo -early At period. In the deepest point of Rudnoe mire the sapropel horizon reaches 3 m (Fig. 2). It was accumulated there from the Bo-period to the middle or even to the end of the At-period. Simultaneously wood,birch and wood-reed eutrophic peats were accumulated on the slopes and at elevated places of the mire depression.

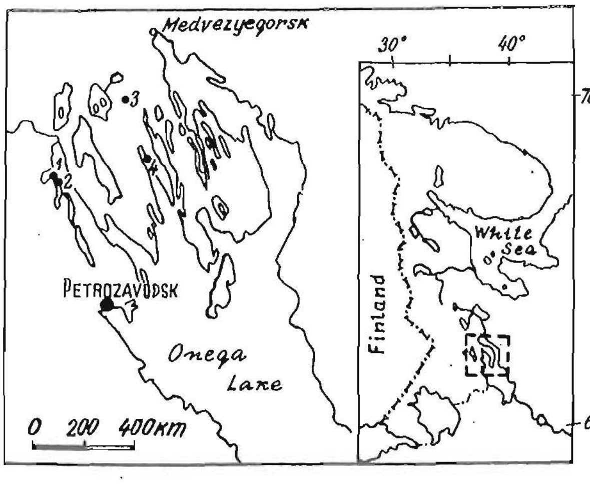

Fig 1. The location of the mires studied.
1 – Rudnoe mire.
2 – Beryosovoe mire.
3 – Moshnoe mire.
4 – Razlomnoe mire system.

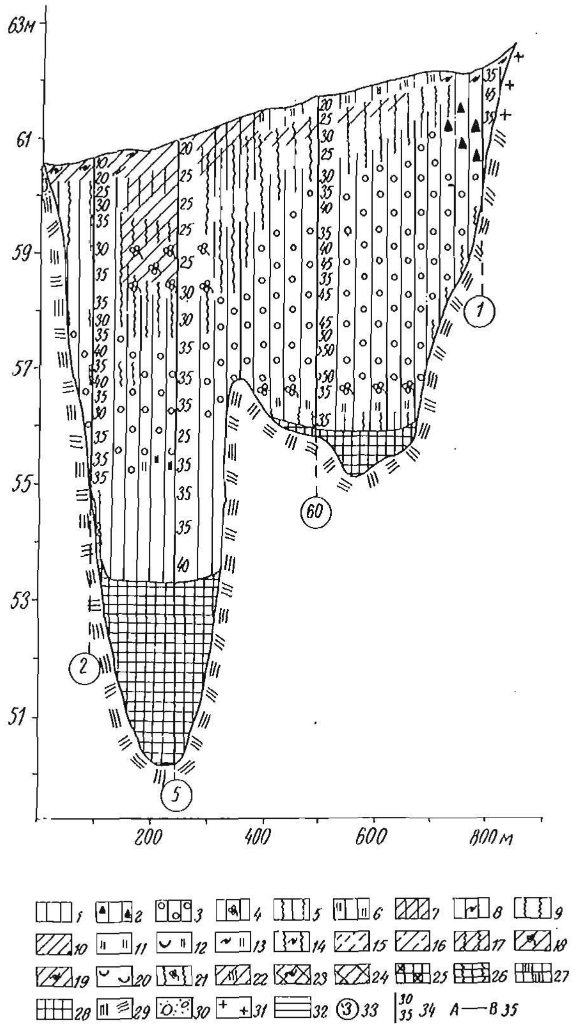

Fig. 2. The longitudinal section through the genetic centre of Rudnoe mire.
The horizontal axis shows the height above sea level.
The vertical axis shows the distance along profiles.

Symbols for Figs. 2-5 and 7:

Eutrophic peats 1-22:

1 – Wood.
2 – Spruce.
3 – Birch.
4 – Wood-bogbean.
5 – Wood-reed.
6 – Wood-herb.
7 – Wood-sedge.
8 – Wood-Sphagnum.
9 – Reed.
10 – Sedge.
11 – Herb.
12 – Molinia-herb.
13 – Sphagnum-herb.
14 – Sphagnum-reed.
15 – Hypnum.
16 – Hypnum-sedge.
17 – Sedge-reed.
18 – Bogbean-sedge.
19 – Sphagnum-sedge.
20 – Molinia.
21 – Bogbean-reed.
22 – Scheuchzeria-sedge.

Mesotrophic peats 22-23:

23 – Sphagnum-sedge.
24 – Sedge.

25 – Sapropel with numerous horse-tail remains.
26 – Reed remains.
27 – Other herb remains.
28 – Pure sapropel.
29 – Massive clay.
30 – Till.
31 – Bedrock.
32 – Varved clay.
33 – Peat hole.
34 – Degree of decomposition.
35 – Stratigraphic profile.

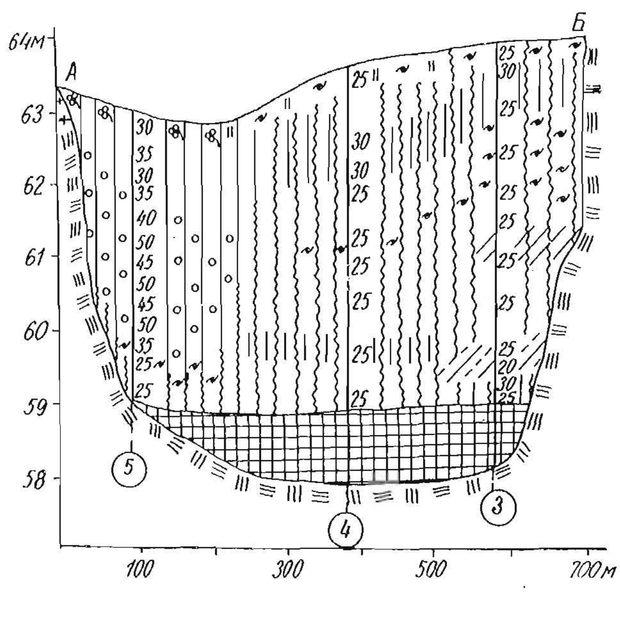

Fig 3. The longitudinal section through the genetic centre of Beryosove mire.
For the legends see Fig. 2.

Peat deposit of Rudnoe mire consists mostly of wood, birch and reed-wood eutrophic peats. Their degree of decompostion (R) varies from 30 to 50%. Only at the north-eastern margin the upper layer(1-2 m) is formed of sedge and sedge-Sphagnum eutrophic peats (R= 20-25%). It is noteworthy that eutrophic spruce peat,which is of rare occurrence in Karelia, was found in the peat deposit of Rudnoe mire. Eutrophic reed peat and its derivatives(R= 20-30%) are the basis of Beryosovoe mire peat deposit and only a small portion (about 15%) falls on highly humificated (R= 50%) wood peat (Fig. 3). It is obvious that Beryosovoe mire was developed under the same conditions of constant and abundant moistening, but under less,than on Rudnoe where mire water flowing of the kettle was caused by slight surface gradient.

The recent vegetation of both Rudnoe mire and Beryosovoe mire consists of wood-herb, sedge and sedge-moss eutrophic plant communities in the central parts and wood-reed or wood-herb-moss coenoses at the edges.

Moshnoe mire (26 ha) is situated about 5 km south-West of Kjappeselga village, Medvezhyegorsk district(Fig. 1).It has been formed in a narrow tectonic crack in the bedrock composed of gabbro-diabases. In the genetic centre its peat deposit is formed by eutrophic sedge peat and its derivatives (Sphagnum-sedge, Hypnum-sedge etc.). The degree of decomposition varies from 15 to 35 % (Fig. 5). Constant and abundant moistening excluded the possibility of wood layer formation in the central part of the mire for all the stages of the mire history. On the other hand wooded communities were developed quite well in the marginal parts of the mire (Fig. 4). Nowadays the plant cover of Moshnoe mire is formed of sedge-moss eutrophic coenoses in the central part. Wood-herb Sphagnum mesotrophic-eutrophic or eutrophic communities occur at the north and south margins (Fig. 4). The site between Lake Taglampi and the mire is occupied by the plant community with the dominance of *Alnus glutinosa.*

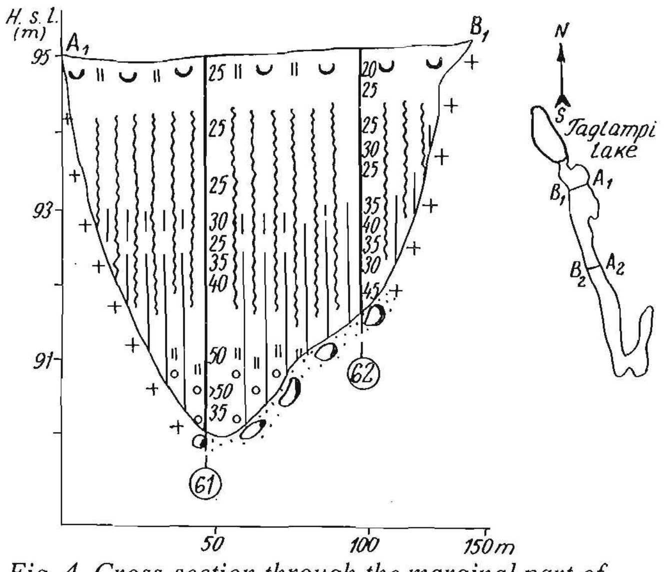

Fig. 4. Cross-section through the marginal part of Moshnoe mire. For the legends see Fig. 2.

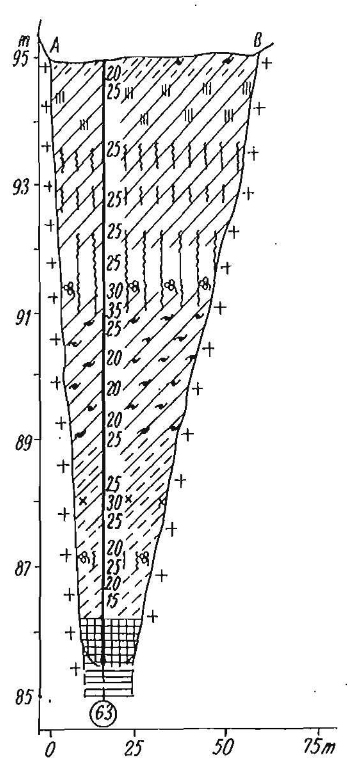

Fig. 5. Cross-section through the genetic centre of Moshnoe mire.For the legends see Fig. 2.

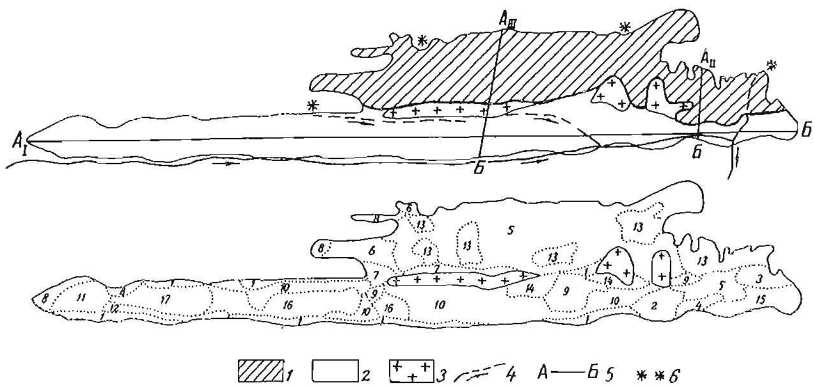

Fig. 6. Razlomnoe mire system.
Upper part –The scheme of the mire system.
1 – Sloping fen. 4 – Brooks and streams with an open or burial bed.
2 – Ravine mire. 5 – Stratygraphic profiles (lines)
3 – Bedrock outcrops. 6 – Springs.
Lower part – The distribution of plant communities.
1 – Piceeta-Herbeta E.
2 – Pineto-Phragmiteto-Cariceta lasiocarpae E.
3 – Betuleto Pineto-Herbeta E.
4 – Piceeto-Molinieto-Sphagneta warnstorfii E.
5 – Pineto-Phragmiteto-Sphagneta warnstorfii E.
6 – Pineto-Cariceto-Sphagneta warnstorfii E.
7 – Pineto-Baethryneto-Sphagneta warnstorfii ME.
8 – Betuleto-Herbeto-Mixtosphagneta M.
9 – Cariceta lasiocarpae E.
10 – Phragmiteto-Cariceto - Hyometa E.
11 – Cariceto-Herbeto-Mixtosphagneta M.
12 – Menyantheto-Sphagneta fallaxi M.
13 – Pineto-Molinieto-Sphagneta warnstorfii ME + Herbeta E.
14 – Pineto-Herbeto-Sphagneta warnstorfii.
15 – Herbeto-Sphagneta warnstorfii ME + Herbeta E.
16 – Herbeto-Sphagneta magellanici M + Cariceto-Sphagneta obtusi ME + Cariceto-Hypneta E.
17 – Herbeto-Sphagneta magellanici (Sphagneta angustifolii) M + Cariceto-Hypneta E.

Razlomnoe mire system is situated on Zaonezhskyi Peninsula (Fig. 1) and it occupies the depression between the ridges composed of effusive diabases. It is adjacent to the northern end of Lizhma Bay of Lake Onega. The depression, filled with limnic and mire sediments, is confined to the long-live sault, through which tectonic movements continue up to the present (Lukashov 1976). The mire system consists of two mires: the mire in the tectonic sault (ravine mire) and adjacent to it slope fen (Fig. 6). The total area of the system is 33 ha, 13 ha of which is covered by the ravine mire. The area of the slope fen is 20 ha.

The plant cover of the system generally consists of presented by eutrophic and mesotrophic-eutrophic communities. (Fig.6).

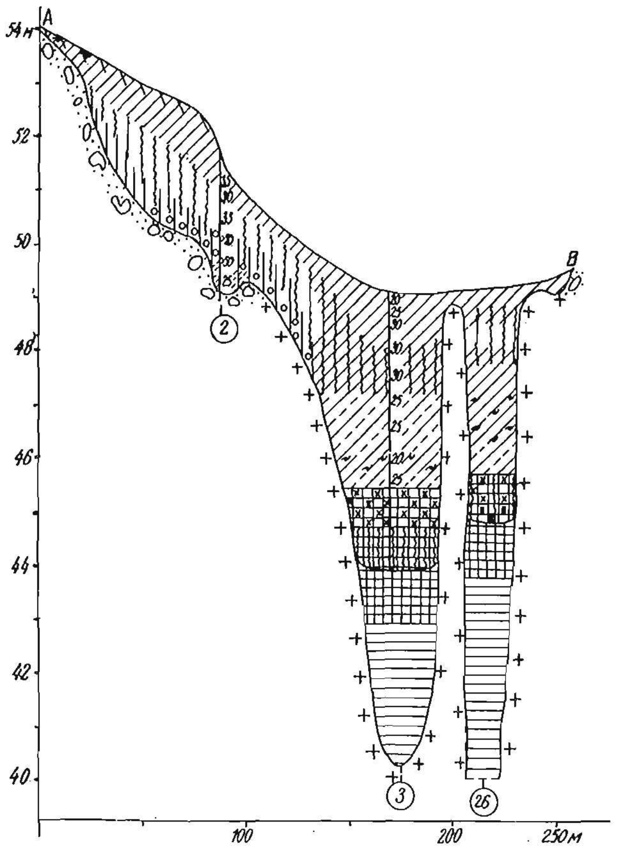

Fig. 7. The cross stratigraphic section through the slope and ravine units of Razlomnoe mire

The peat deposit of the ravine mire is of eutrophic type. It is fairly heterogeneous in its structure and can be divided into three parts along the longitudinal section (Shevelin et al. 1988). The first part (farthest from the bay) is formed of wood and wood-herb peats, the second (central) of sedge peat and the third part (adjacent to the bay) of wood-sedge and wood peats. The contacts between the parts are broken, poorly interpreted. The significant disturbance of the deposit structure is likely to be connected with new tectonic movements in bedrocks observed in this region. These data are supported by radiocarbon datings and pollen-spore analyses of a number of mire sections. In figure 7 the cross stratigraphic section through the slope and ravine units of the mire system is presented (Fig. 6, profile AII-B). Displacement in the stratigraphy of the ravine mire is one more evidence for the new tectonic activity observed.

The peat deposit of the slope fen is referred to the eutrophic type, but it is of more simple structure than the ravine mire peat deposit. In the genetic centre the bottom layer is formed of birch or birch-pine peats. The surface strata of peats are sedge or sedge-Sphagnum peat. A very thick horizon of wood-reed and reed peats is generally found between them.

Palynological and radiocarbon analyses of sediments from the genetic centre of the ravine mire testify to the accumulation of clays during the DR3-BO(7 200±100), and sapropels and sapropel-like peats in the At-period (5 500±100). The true peats began to form only 2 000 years ago (1 980±60). The subboreal sediments are completely lacking, and they are very fragmentary in the BO-time. At the same time in the At period the sedimentation was very rapid, 2 mm/year. A similar phenomena was not observed earlier for such sections.

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THE USE OF PEAT BOTANICAL COMPOSITION FOR RECONSTRUCTION OF ECOLOGICAL CONDITIONS OF MIRE PLANT COMMUNITIES

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1 Introduction

Numerous studies have shown that peat is a derivative of a plant cover, and in most cases it reflects the characteristics of maternal phytocenoses (Gerasimov 1932, Bogdanovskaya-Guiheneuf 1945, Abramova 1947, Shirokovskaya 1947, Grebenshchikova 1956, Botch 1958a, 1958b, 1964, Pjavchenko 1978, Elina et al. 1984). However, most mire plants are easily decomposed and only *Sphagna* and some *Bryales* species are more resistant to humification (Kozlovskaya et al. 1964, 1978, Kozlovskaya 1972, 1976, Egorova 1975, Botch 1976, 1978, Germanova 1978).

The botanical analysis of a vast peat material from Karelia (over 6000 analyses) performed by G. A. Elina, O. L. Kuznetsov and A. I. Maksimov (1984) has revealed the composition of major plant peat-formers. They include 23 taxa: *Eriophorum vaginatum, Carex lasiocarpa, C. rostrata, C. limosa, Pinus sylvestris, Scheuchzeria palustris, Equisetum fluviatile + E. palustre, Menyanthes trifoliata, Betula pubescens, Phragmites australis, Sphagnum balticum, S. magellanicum, S. angustifolium, S.* sect. *Cuspidata, S. fuscum, S.* sect. *Acutifolia, Drepanocladus* spp., *Sphagnum majus, S. papillosum, Meesia triquetra, Sphagnum teres, S. warnstorfii* and *S.* sect. *Subsecunda.*

About 95 % of peat types known in Karelia are composed of the above species. In addition to the above plants 25 other species were found in peat. However, their occurence was less than 1 %.

Based on our ecological studies on *Sphagnum* and those on vegetational reconstruction (Elina et al. 1984) we made an attempt to reconstruct the ecological conditions of plant development at two mire sites during the Holocene.

2 Study region and methods

The mire sites studied differ in their mineral nutrition and are located in the central and eastern portions of Nenazvannoe mire (Kindasovo field station, southern Karelia, Fig. 1).

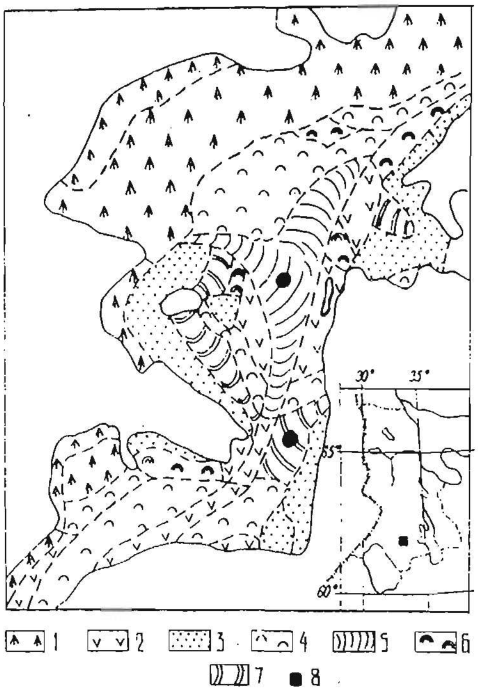

Fig 1. The mire site types of Nenazvannoe.
1 – Mesotrophic-hummock plain Pineto-Sphagneta magellanici + S. angustifolii-fallaxi.
2 – Mesotrophic carpet Sphagneta angustifolii or S. fallaxi.
3 – Oligotrophic pattern structure Sphagneta fusci or S. angustifolii with rare pine.
4 – Hummock-hollow mesotrophic-eutrophic Sphagneta centralis + S. obtusi - Drepanocladeta or mesotrophic Sphagneta magellanici + Menyantheto-Cariceto limosi.
5 – Mesotrophic hummock-hollow-pool or hummock-hollow Sphagneta papillosi or S. magellanici-fusci - Menyantheto-Cariceta limosi - pools (aapa complex).
6 – Oligotrophic hummock-hollow Sphagneta fusci + S. baltici.
7 – Oligotrophic ridge-hollow Sphagneta fusci + S. baltici or S. majoris.
8 – Location of Nenazvannoe.
9 – Peat coring points.

Nenazvannoe was formed on a hilly-ridge moraine plain between high ridges composed of bedrocks and washout moraine. Abundant ground water supply in northern and south-western parts of the mire provides a constant inflow of mineralized waters. All this contributes to a complex and mixed pattern in the mire hydrology and plant distribution in it (Elina 1981). In terms of plant distribution in the centre and in the margins the mire is referred to the South-Karelian variant of the aapa type (Elina 1977).

The stratigraphy of mire sites was studied using a Russian peat sampler. The samples for laboratory analyses were also obtained with a Russian sampler.

The degree of humification and botanical composition of peat were measured by the traditional macroscopic method used in Russia.

Samples were ashed in a muffle furnace at 450 °C. The ash was analyzed for element content by atomic absorption spectrometry (AAS-1) after the treatise with mineral acid solution HF + H_2SO_4. P, S and Si were determined by chemical method. The results are expressed in volumetric weight.

3 Results and discussion

One core was taken in a ridge of the ombrotrophic ridge-hollow site (Fig. 1). The mire was initiated at this site in late BO - early AT periods. Eutrophic *Carex-Equisetum-Bryales* communities were predominant at that time. They were soon replaced by eutrophic sedge-*Sphagnum* phytocenoses with dominant *Sphagnum* mosses from Sect. *Subsecunda* in the ground layer (Fig. 2). Eutrophic plant communities developed under conditions of poor ground water nutrient supply because calcium and magnesium content in minerotrophic in their botanical composition peats is much lower than the average values for Karelia (Maksimov 1988). At the first stages of the mire development the defficiency of mineral elements in ground water seemed to be compensated by good flowage of mire waters. This is evidenced by the presence of bogbean and horsetail remains in peat. The eutrophic stage of the mire development is rapidly changed into a mesotrophic one that is induced by the appearance of ombrotrophic *S. magellanicum* and *S. angustifolium* (Fig. 2). Small amounts of ombrotrophic *S. fuscum* are found in *Sphagnum* macrofossils in early Sub-Boreal period. *S. fuscum* and *S. angustifolium* are co-dominants of oligotrophic cottongrass-*Sphagnum* communities, and in the Sub-Atlantic period *S. fuscum* gradually becomes a major edificator of phytocenoses which receive mineral nutrients only through the atmosphere. The absolute dominance of *S. fuscum* in the plant cover coincides with a very low content of calcium and magnesium in peats (Fig. 2, Table 1).

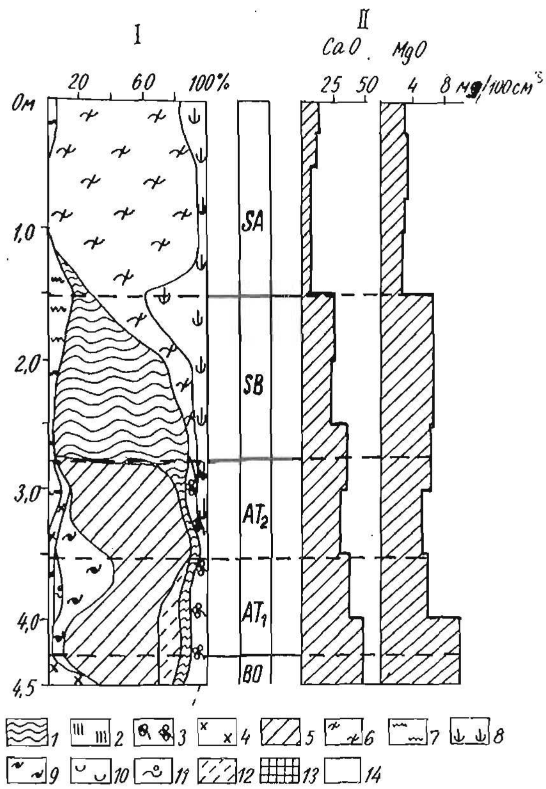

Fig 2. Peat deposit composition of an oligotrophic ridge-hollow site Sphagneta fusci + S. baltici under a ridge, Nenazvannoe, and dynamics of alkaline-earth metal content in different Holocene periods.
1-12 – Pant remains in peat.
1 – Cottongrass.
2 – Scheuchzeria palustris.
3 – Menyanthes trifoliata.
4 – Equisetum spp.
5 – Carex spp.
6 – Sphagnum fuscum.
7 – Sphagnum magellanicum.
8 – Sphagnum angustifolium.
9 – Sphagnum sect. Subsecunda.
10 – Sphagnum obtusum.
11 – Sphagnum teres.
12 – Bryales.
The right column presents Holocene periods showing the age of peat layers:
SA – Sub-Atlantic.
SB – Sub-Boreal.
AT – Atlantic.
BO – Boreal.

The next core was taken on a hummock composed of *S. magellanicum* at a hummock-hollow mesotrophic site (aapa mire). It is located in the central part of the mire. The mire development in this site was a gradual process as a result of overgrowth of a shallow water body with a sedge-horsetail floating mat. Sedge communities of *Carex lasiocarpa* began to develop only in the middle of AT-1. The amounts of mosses from *Sphagnum* Sect. *Subsecunda* (Fig. 3) are small. The appearance of *Sphagnum* at the initial stages of the mire development shows that it received mineral nutrient from poor ground waters. This is also evidenced by the presence of *Scheuchzeria palustris* remains in peat resulting from poor mineral nutrition and stagnant water regime at the

Table 1. Macroelement content (mg/100cm^3) in a peat deposit under ridge of ridge-hollow ombrotrophic site *Sphagneta fusci* + *S. baltici* in Nenazvannoe.
D – Depth, m.
Type – Peat type.
R. – Rate of decomposition.
Ash – Ash content, %.

D	Type	R.	Ash	K_2O	Na_2O	CaO	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Fe_2O_3	Mg/Ca	Mg/Fe
0.25	fuscum ombrotrophic	0-5	2.29	4.3	0.9	13.1	2.81	6.4	15.8	-	5.2	3.5	0.22	0.80
0.50	fuscum ombrotrophic	5	1.31	3.3	1.5	10.1	3.0	4.5	13.9	3.1	6.8	3.1	0.30	0.97
0.70	fuscum ombrotrophic	5	1.20	1.8	0,8	6.6	2.9	4.4	17.9	2.5	7.1	3.6	0.44	0.80
1.00	fuscum ombrotrophic	5	1.35	1.3	1.7	7.0	2.8	5.1	21.2	2.2	8.0	3.8	0.40	0.74
1.20	fuscum ombrotrophic	5	1.23	1.1	1.0	6.6	2.4	4.1	21.1	-	-	3.4	0.36	0.70
1.50	sphagnum complex ombrotrophic	5	1.15	1.1	1.1	7.0	2.4	4.0	18.2	2.2	4.7	3.7	0.34	0.65
2.00	cottongrass sphagnum ombrotrophic	50	1.18	3.9	3.6	24.7	6.7	28.0	70.1	8.7	20.9	16.0	0.27	0.42
2.50	cottongrass ombrotrophic	50	0.94	3.6	2.4	23.1	6.7	20.7	44.2	5.9	22.6	19.0	0.29	0.35
3.00	cottongrass ombrotrophic	50	1.13	3.7	3.1	34.6	6.4	25.4	26.4	7.2	30.5	35.6	0.18	0.18
3.50	sedge-sphagnum mesotrophic	25	1.71	2.5	2.3	29.5	5.2	24.5	24.0	5.0	19.5	41.3	0.18	0.09
4.00	sedge-sphagnum eutrophic	30	2.02	3.3	2.5	37.2	5.9	32.8	29.1	5.7	32.8	64.5	0.15	0.09
4.40	sedge eutrophic	30	3.14	5.5	6.1	51.2	9.1	53.9	87.4	6.8	58.1	103.4	0.18	0.09

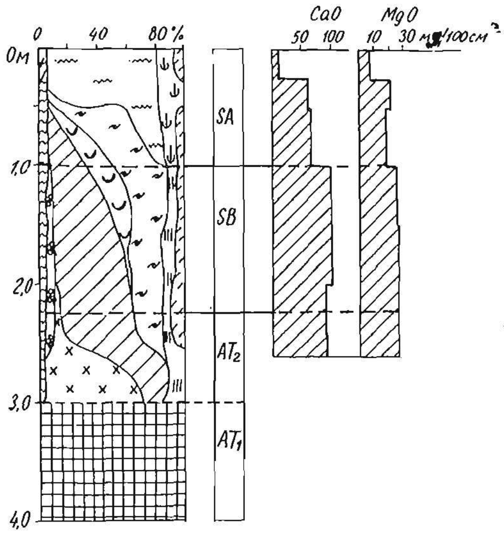

Fig. 3. Peat deposit composition of mesotrophic hummock-hollow site Sphagneta magellanici-fusci + Menyantheto-Cariceta limosi Nenazvannoe under a hummock and dynamics of alkaline-earth metal content in different Holocene periods. For legends see Fig. 2.

mire site. The concentration of calcium and magnesium does not exceed the average values for Karelia (Maksimov 1988). As a result of gradual peat accumulation, the peat moss species *Sphagnum subsecundum* and *S. contortum* become co-dominants of the plant cover approximately in early SB (Fig. 3). In the middle of SB simultaneously with the appearance of *Sphagnum obtusum* in the plant cover *Sphagnum* mosses begin to play the role of co-edificators in several phytocenoses of the mire site. *Sphagnum*-dominated communities are likely to give rise to carpet formation and contribute to the development of microcomplexes in the plant cover of the mire site. On the microelevations formed eutrophic *Sphagnum subsecundum* and *S. obtusum* become edificators of phytocenoses and by acidifying the habitats they create favourable conditions for the expansion of mesotrophic species (*S. centrale*) and then oligotrophic ones, such as *S. angustifolium* and *S. magellanicum*. They were found in early Sub-Atlantic period, and since the middle of SA *S. magellanicum* begins dominating on hummmocks (Fig. 3). Approximately at that time oligotrophic conditions were created on hummocks that is evidenced by a sharp decrease of calcium and magnesium content in this horizon (Table 2). In hollows, on the contrary, where *Sphagnum* mosses are lacking or are very rare, mesotrophic conditions are being preserved up to the present time.

4 Conclusions

Analysis of the role of *Sphagnum* mosses in different Holocene periods allows both to reveal vegetational changes in mire sites in Holocene and to reconstruct the ecological conditions of plant communities. Due to a wide range of their ecological requirements and their often being strong edificators *Sphagnum* mosses contribute to the formation of microrelief and microcomplex character of plant cover at mire sites.

Table 2. Macroelement content (mg/100 cm^3)in a peat deposit under a hummock of hummock-hollow mesotrophic site *Sphagneta magellanici-fusci* + *Menyantheto-Cariceta* in Nenazvannoe.
D – Depth, m.
Type – Peat type.
R. – Rate of decomposition.
Ash – Ash content, %.

D	Type	R.	Ash	K_2O	Na_2O	CaO	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Fe_2O_3	Mg/Ca	Mg/Fe
0.3	magellanicum	0-5	4.61	0.8	0.3	16.5	7.8	2.5	8.7	0.6	3.5	5.0	0.47	1.6
0.5	oligotrophic sphagnum	5	4.28	1.3	0.7	59.6	21.1	6.4	23.3	2.4	13.2	10.5	0.35	2.0
1.0	mesotrophic sedge-sphagnum	15	3.52	2.5	1.0	65.9	17.6	10.8	46.1	2.4	14.7	22.4	0.27	0.78
1.5	mesotrophic sedge-sphagnum	20	3.36	2.3	11.2	102.6	25.9	27.1	51.7	9.8	23.9	46.4	0.25	0.56
2.0	eutrophic sedge	20	3.48	2.3	5.1	102.6	27.0	27.1	-	11.7	39.3	49.6	0.26	0.54
2.5	eutrophic sedge	25	6.50	6.0	8.0	93.9	26.6	54.1	347.6	12.6	64.6	59.1	0.28	0.45
3.0	eutrophic	-	15.87	15.1	16.8	133.7	42.2	197.8	1689.7	13.9	170.7	184.9	0.32	0.23

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MIRE ECOSYSTEMS OF THE VODLOZERSKY NATIONAL PARK, NORTHERN RUSSIA

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1 Introduction

The State natural national park Vodlozersky was established in 1991. It is located in the territory of eastern Karelia (Pudozh district) and the western part of Arkhangelsk region (Onega district). About two thirds of the national park's territory are situated in Arkhangelsk region. The main function of the national park is to conserve the unique piece of the taiga zone in North Europe and to regenerate the cultural historical heritage of the Russian North.

The national park stretches from north to south for 150-160 km and from west to east for 40-50 km. It's total area is 467 thousand hectars (Fig.1). The major part of the territory is located within a glacial plain with absolute heights of 150-200 metres above the sea-level. In the north the height reaches 250-300 metres. The territory is characterized by ridge-hilly relief with numerous lakes of glacial origin (Iljin et al. 1992).

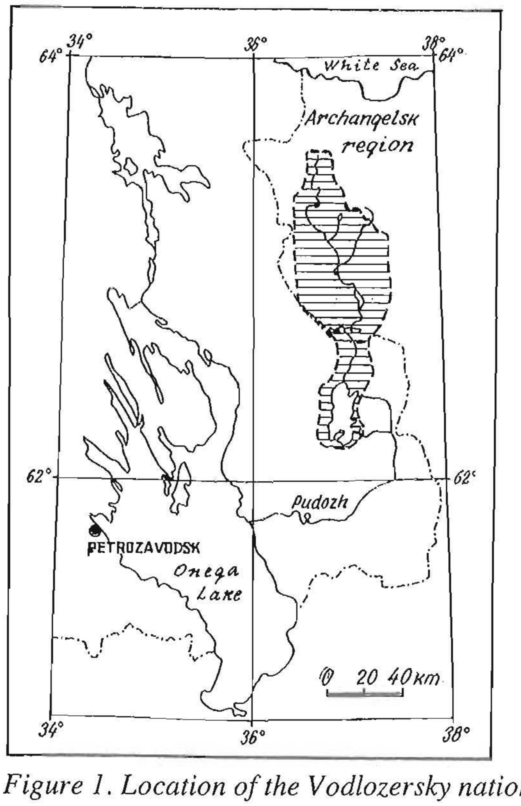

Figure 1. Location of the Vodlozersky national park.

The climate in the area is temperate-continental. The average temperature in January is -10°C, in July +16°C. Mean annual precipitation is 500-600 mm. The thickness of snow cover is 60-65 cm and it is retained for 160-180 days (Romanov 1961).

Wide river network determines the hydrological regime of the national park. The major river is the River Ileksa which has numerous tributaries. The river length is 160 km (Bersonov 1960). There are some shallow running water lakes within the basin of the River Ileksa. The largest of them are Lake Monastyrskoye and Lake Luzkoye. All the rivers and lakes are rich in fish. The Lake Vodlozero, into which the River Ileksa flows, is one of the most beautiful Karelian lakes. Its area is more than 334 km^2 . There are numerous islands with small villages, picturesque meadows and ancient chapels there. The administration of the park is located in the settlement of Kuganavolok in the southern shore of Lake Vodlozero.

The national park is situated in the intersection of two latitude subzones of taiga - north and middle subzones. North-taiga forests cover 10 % of the total territory. They are in the upper Ileksa in the northern part of the national park. They are mainly formed by *Pinetum empetroso-vacciniosum* and *Pinetum empetroso-myrtillosum* associations. The following mire dwarf-shrubs are found in the plant cover of these forests: *Ledum palustre, Empetrum nigrum, Betula nana* and *Vaccinium uliginosum.* Their distribution is determined by the edaphic-climatic conditions of the north-taiga subzone (Tsinzerling 1932). In the subzone of middle-taiga mire dwarf-shrubs do not occur or they are very sparse in the mineral soil forests. The national park's forests in this subzone are formed by associations *Pinetum vacciniosum, Pinetum myrtillosum* and *Piceetum myrtillosum* (Yakovlev & Voronova 1956). Tsinzerling (1932) points the occurrence of Siberian elements in the forests of the eastern part of the middle-taiga subzone. *Lonicera coerulea, Actaea erythrocarpa, Rubus humulifolius* and *Larix sibirica* are rather widespread in the area. Together with forests and water ecosystems mires are an important element of the national park's natural landscapes. The territory is paludified to 40 % and the total area of the mires reaches 230 thousand hectares.

2 Materials and methods

The first research of the mire ecosystems of the national park was carried out in 1987. The mires of Vodlozero basin were studied from 1987 to 1991. The materials of the research underlay the scientific bases for establishing there the landscape partial reserve Vodlozersky. Now it is a national park. In 1992 together with Finnish scientists R. Heikkilä, T. Lindholm, P. Rassi and M. Suoknuuti we studied thoroughly some of the mires in the valley of the River Ileksa. In August of the same year, 9 mires in the Ileksa valley were studied by the authors of this report. The route was from the Tun lake to the River Novguda (Fig.2). The flora, vegetation, peat deposits and the structure of mire complexes were investigated. Additional information on the structure of the mires was available via aerial surveys of the national park's territory. The data were analyzed and extrapolated on the studied mires by the aero-surface method after E. Galkina (1964). Geobotanical characteristics of the major (or dominant) types of the national park's mire bodies are given in the present work.

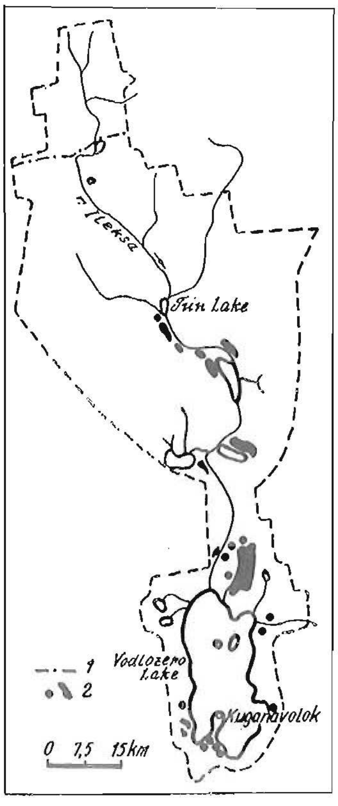

Figure 2. The investigated mire in the Vodlozersky national park.
1 – the boundary of northern and middle subzones
2 – the investigated mires.

3 Results

3.1 Mire types of the national park

Four mire types different in the structure of their plant cover and water-mineral nutrition dominate in the territory of the national park.

According to T.K. Yurkovskaya (1980) the types are: 1. Oligotrophic eccentric ridge-hollow Pechora-Onega bogs; 2. Oligotrophic pine dwarf-shrub - cotton grass - *Sphagnum* north-eastern-European bogs; 3. Onega-Pechora aapa mires; 4. Mesotrophic herb-*Sphagnum* mires. It should be noted that the first three mire types are found only in Arkhangelsk region and eastern Karelia, i.e. on the western boundary of their distribution area.

3.2 Oligotrophic eccentric ridge-hollow Pechora-Onega bogs

Oligotrophic eccentric ridge-hollow Pechora-Onega bogs amount to 40 per cent of the mire area. In the central part of the bogs the surface is slightly convex. Oligotrophic hummock-hollow, ridge-hollow or ridge-hollow-pool sites *Sphagneta fusci + S. baltici* may be formed here. *Pinus sylvestris, Chamaedaphne calyculata, Andromeda polifolia, Empetrum nigrum* and *Oxycoccus microcarpus* are usually abundant in the ridges and hummocks. *Eriophorum vaginatum, Rubus chamaemorus* and *Carex pauciflora* are widespread in the area. The moss cover is formed by *Sphagnum fuscum, S. angustifolium. Sphagnum magellanicum* and *S. nemoreum. Polytrichum strictum, Pleurozium schreberi, Cladina arbuscula* and *C. rangiferina* synusia also occur in the area.

The plant cover of the hollows and especially pools is rather poor. Some individuals of *Andromeda polifolia* and *Chamaedaphne calyculata* grow there. Their abundance is less than 15 %. The grass cover varies from 1 to 20-40 %. *Carex limosa, Scheuchzeria palustris* and *Eriophorum vaginatum* are common in hollows. The moss cover of the hollows is formed by *Sphagnum balticum* and *S. majus* with some *S. angustifolium* and *S. magellanicum.* Synusia *S. rubellum* and *S. russowii* were sometimes observed in the hummock-hollow contact zones.

In the hollows and pools of the ridge-hollow-pool bog sites *Sphagnum papillosum* and *S. lindbergii* and along the ridge edges *Rhynchospora alba* grow.

In the marginal areas of Pechora-Onega bogs oligotrophic bog sites *Pineto-Sphagneta angustifolii, Pineto-Sphagneta fusci* and *Sphagneta angustifolii* are formed. Their species composition is very poor (Antipin 1991). Mesotrophic *Pineto-Sphagneta* bog sites are also usual in marginal parts of Pechora-Onega bogs. Pine and dwarf shrubs as well as *Carex lasiocarpa, Eriophorum angustifolium* and *Menyantes trifoliata* are widespread there. *Sphagnum fallax* and *S. angustifolium* are edificators of the plant associations.

Between the marginal and central parts of Pechora-Onega bogs mesotrophic *Sphagneta fallaxi* and *Cariceta* mire sites are sometimes formed. They usually represent water tracks with rich flora. This complicates, to a certain extent, the plant cover structure of Pechora-Onega mires.

3.3 Oligotrophic pine dwarf-shrub - cotton grass - *Sphagnum* north -eastern European bogs

Oligotrophic pine dwarf-shrub - cotton grass - *Sphagnum* north-eastern European bogs are also widespread in the national park. They cover about 15 % of the area. They are formed in water-glacial depressions, and their bottom consists of sand, pebbles and boulders. *Calluna vulgaris* and western *Sphagnum* species do not occur there. *Sphagnum rubellum, S. tenellum* and *S. cuspidatum* are rare in the plant cover of the hollows (Yurkovskaya 1980).

The tree layer of the bogs is formed by *Pinus sylvestris* f. *uliginosa* and *P. sylvestris* f. *litvinowii. Eriophorum vaginatum, Rubus chamaemorus, Chamaedaphne calyculata* and *Ledum palustre* are dominant in the ground layer. The moss cover consists of *Sphagnum angustifolium, S. magellanicum* and *S. fuscum* as well as patches of S. *nemoreum* and *S. russowii.*

In the marginal parts of the bogs *Carex lasiocarpa* and *C. rostrata* are common and *Carex omskiana* occurs in the areas flooded by the River Ileksa waters.

3.4 Onega-Pechora aapa mires

Onega-Pechora aapa mires as well as Pechora-Onega bogs are also widespread in the national park. These mires cover about 40 % of the area. They are characterized by very flooded central parts where meso-oligotrophic, mesotrophic and meso-eutrophic flark, hummock-flark and string-flark mire sites are formed.

In the flarks there usually are mesotrophic and meso-eutrophic *Cariceta* mire sites. *Carex lasiocarpa, Menyanthes trifoliata, Carex limosa* and *Equisetum fluviatile* grow there. *Eriophorum angustifolium, E. gracile, Carex chordorrhiza* and *Ledum palustre* occur in the area. *Juncus stygius* occurs also there but it is very rare. The moss cover is usually formed by *Sphagnum subsecundum, S. teres, S. fallax, S. papillosum, S. obtusum* and *Drepanocladus exannulatus* synusia. The hummock-flark parts of Onega-Pechora aapa mires are formed by mesotrophic sites *Sphagneta + Herbeta. Sphagnum papillosum* and *S. fallax* as edificators grow on hummocks. The herb cover covers up to 60-70 %. There is *Carex lasiocarpa* in the hummocks. *Menyanthes trifoliata, C. limosa* and *Equisetum fluviatile* grow in the flarks. In the ground layer *Sphagnum teres, S. subsecundum, S. fallax, S. aongstroemii* and species of genus *Drepanocladus* occur.

Meso-oligotrophic mire sites *Sphagneta fusci + Sphagneta papillosi* + pools have a distinctive structure of the plant cover. *Sphagnum fuscum* and *S. papillosum* are usual in the hummocks. *Sphagnum papillosum, S. majus, S. balticum, S. jensenii* and *Carex limosa* grow in the flarks. At this sites *Carex lasiocarpa* is very rare, but *Rhynchospora alba* occurs.

The string-flark patterns are presented by mesotrophic sites *Sphagneta papillosi + Cariceta* and *Sphagneta fallaxi + Cariceta.* The plant cover of strings of mire sites *Sphagneta papillosi + Cariceta* is formed by *Sphagnum papillosum, Andromeda polifolia, Chamaedaphne calyculata, Menyanthes trifoliata* and *Carex limosa. Trichophorum cespitosum* and *Rhynchospora alba* also grow there. *Carex limosa* is abundant in the flarks. The flarks are covered with *Sphagnum majus, S. compactum* and *S. obtusum* but not more than by 10 -15 %. It should be noted that we found *Molinia coerulea* in the Onega -Pechora aapa area for the first time, while T. Yurkovskaya (1980) investigating fens of this type in Arkhangelsk region noticed that *Molinia coerulea* was not observed there.

At the mesotrophic string mire sites *Sphagneta fallaxi + Cariceta* the plant cover is mainly formed by *Carex rostrata* and *Sphagnum fallax. Sphagnum papillosum* may also be found there. The moss cover (*Sphagnum majus*) in the flarks does not exceed 40-50 %. In the field layer the cover of *Carex limosa, C. rostrata* and *Scheuchzeria palustris* amounts to 5-10 %.

3.5 Mesotrophic herb-*Sphagnum* mires

Mesotrophic herb-*Sphagnum* mires are mostly located in the valley of the River Ileksa. Many of them are covered by flood in spring.

Mesotrophic sites *Sphagneta fallaxi* are prevalent in the mires. The surface of the mire sites may be either flat, hummock and carpet or hummock, carpet and flark. In the hummocks grow dwarf shrubs, *Eriophorum vaginatum, Scheuchzeria palustris* and *Menyanthes trifoliata*. The association edificators are *Sphagnum angustifolium* and *S. magellanicum. C. lasiocarpa, Eriophorum angustifolium, E. gracile* and *Sphagnum centrale* grow in the hummocks in the marginal parts of the mires. The carpet sites *Sphagneta fallaxi* are covered with sedge-*Sphagnum* associations with *Carex rostrata,* *Menyanthes trifoliata, Sphagnum fallax, S. flexuosum, S. papillosum* and *S. riparium*. At those sites associations with *Carex omskiana* and *Sphagnum fallax* were identified and described for the first time. *Menyanthes trifoliata* and *Carex limosa* grow in the flarks. The edificator of the hollow plant associations is *Sphagnum majus*.

Besides the above mentioned mire types there are some small mesotrophic dwarf-shrub - sedge - *Sphagnum* fens with pine and birch and eutrophic forest swamps in the national park. They develop under rich mineral nutritional conditions. The flora of these mires is characterized by high species diversity and rich vegetation and complex structure. This kind of mires has not yet been investigated thoroughly in the national park.

It should be noticed that the major part of mires in the national park forms complex mire systems with the area of more than 5 thousand hectares.

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THE EFFECT OF CLIMATIC CONDITIONS ON THE ANNUAL INCREMENT OF SPHAGNA IN SOUTHERN KARELIA

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1 Introduction

The *Sphagna* play a leading role in the plant cover, production process and turnover in both mesotrophic and oligotrophic mires. The succession and lifetime of mire phytocenoses of a mire are closely related to the tolerance range of relevant plants. Grime et al. (1990) have noted that moss-like plants adapt to environmental changes physiologically rather than morphologically. Most moss-like species are relatively resistant to drying. They usually grow when their tissues are in a hydrated state for a long time. Generally, the response of moss-like plants to seasonal humidity and temperature variations is still poorly understood. When studying the biology of *Sphagna*, it is important, therefore, to assess the effect of both ecologo-cenotic and climatic conditions on their growth dynamics and biological productivity during their growing season.

The *Sphagna* are characterized by the unlimited apex growth of their stem and the permanent dying-out of their lower part. It is known that mosses begin to grow immediately after the snow goes off and their linear increment depends on moss species, groundwater level, climatic conditions and nutrient content (Clymo 1970, Ilomets 1981, Lindholm 1990).

A comprehensive review of literature on the estimation of annual increment in *Sphagna* was made by Kats et al. (1936). More recently, studies have been conducted and reviews made by Clymo (1970, 1973), Ilomets (1981), Maksimov (1982), Grabovik and Antipin (1982), Moore (1989), Lindholm (1990), Lindholm & Vasander (1990) and Grabovik (1991 a,b). Maksimov (1982) also determined the growth increment of *Sphagna* in spring, summer and autumn. According to his data, maximum linear increment is usually observed in spring and in autumn.

It should be noted, however, that the data on the growth increment of mosses are scarce. The studies of the above mentioned authors lasted one to two years. Different methods were used, but the effect of climate on mosses during their growing season was disregarded. It is difficult, therefore, to draw any conclusions about the value of increment in *Sphagna* during one season not only in different communities, but even in different geographic zones.

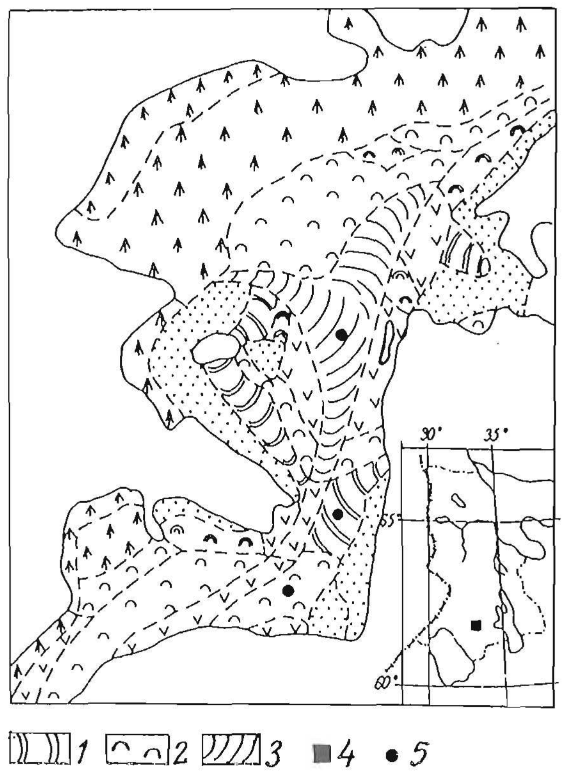

Fig. 1. Scheme of Nenazvannoe mire.
Symbols:
1 – Ombrotrophic ridge-hollow Sphagneta fusci + Sphagneta baltici complex.
2 – Minero-ombrotrophic hummock-hollow Sphagneta majoris complex.
3 – Mesotrophic hummock-hollow Sphagneta papillosi + Herbeta complex.
4 – Location of Nenazvannoe mire.
5 – Investigated plots.

2 Material and methods

The studies were made in 1979-1988 as a part of comprehensive investigations of the structure, productivity and dynamics of mire ecosystems in the Kindasovo Forest and Mire Experimental Research Station by the Karelian Research Center (Fig.1).

Weather conditions were highly variable during the study period and deviated from available long-term data (Table 1). According to long-term observations, the growing season in the experimental area varies from 145 to 175 days (average 152 days). Spring begins in late April - early May when air temperatures above +5°C are stable. Summer begins approximately on 15th June when daily temperatures are above +15°C and the flowering of *Vaccinium oxycoccos* begins. About the 15th of August, air temperatures start to decrease below 15°C which indicates the autumn. At this time of year *Vaccinium uliginosum* leaves attain "fall colours". In the study area, the growing season is usually over by mid-October.

The study of linear increment in *Sphagna* was made in three mire sites where the mosses are plant cover edificators, but they grow under different mineral nutrition and moisture conditions. The plant cover of each site was described by geobotanical methods (Fig.1).

The tying-up method was used to estimate annual linear increment. In spring, sites dominated by *Sphagnum fuscum* (Schimp.) Klinggr., *S. papillosum* Lindb., *S. majus* (Russ.) C. Jens. and *S. balticum* (Russ.) C. Jens. were selected. A piece of thread was tied round 50-100 moss plants at a distance of 1 cm from the apex of the plant. At the end of the period the distance of thread from the apex of the plant was measured. During the study period mosses to be tied were selected at the same sites, but the part of the plants to be tied were different.

Table 1. Climatic conditions in the course of the study.

Year	Precipitation, mm				Length of the growing season, days
	Spring	Summer	Autumn	Total	
1979	84.0	76.0	54.8	214.8	153
1980	34.0	78.0	58.0	170.0	154
1981	115.5	161.4	142.9	419.8	163
1982	118.4	144.0	88.0	350.4	163
1983	128.6	100.2	102.3	331.1	163
1984	85.8	102.5	132.3	320.6	165
1985	52.2	108.4	86.2	246.8	145
1986	107.8	181.3	148.3	437.4	148
1987	208.0	226.5	133.5	568.0	175
1988	82.1	200.9	120.1	403.1	173

According to Lopatin (1973), *Sphagnum fuscum* belongs to a hydrophilic-psychrophilic hummock-ridge group and can withstand considerable drying for a long time. *Sphagnum papillosum* represents a subpsychrophilic carpet group and can tolerate short moderate drying. *Sphagnum balticum* and *S. majus* belong to a hyperhydrophilic hollow group and cannot resist drying.

Mire site 1 is an ombrotrophic ridge-hollow *Sphagneta fusci* + *Sphagneta baltici* complex. To estimate increment in *Sphagnum fuscum*, measurements were made in the microcenoses located on top of each ridge in the ecological succession: upper part of ridge - slope of ridge ridge-hollow contact. *Sphagnum balticum* was measured in hollow microcenoses (Table 2).

Mire site 2 is a minero-ombrotrophic hummock-hollow Sphagneta papillosi + *Sphagneta majoris* complex. The moss cover is compact and thick. The site has a permanent flow moisture regime and is well-drained. It is located near the brook into which surface and internal mire water is discharged. The increment of *Sphagnum papillosum* was measured here in low hummock microcenoses and that of *S. majus* in moss hollow microcenoses (Table 2).

Mire site 3 is a mesotrophic hummock-hollow *Sphagneta papillosi* + *Herbeta* complex. The increment of *Sphagnum fuscum* was measured in low flat hummock microcenoses and that of *S. papillosum* in carpet microcenoses (Table 2).

3 Results and discussion

This study has shown that the linear increment of each species varies greatly within one community from year to year. Besides, there were differences in increment between the communities investigated.

Table 2. Characteristics of mire sites.

	Mire sites					
	1		2		3	
Microrelief	ridge	hollow	hummock	hollow	hummock	hollow
Cover % of the site	60	40	25	75	24	76
Nutrient conditions	ombrotrophic	ombrotrophic	mesotrophic-ombrotrophic	mesotrophic	mesotrophic-ombrotrophic	mesotrophic
Water level cm	-40 - -60	-2 - -4	-5 - - 10	1 - -3	-24 - -30	50 - 75
Species	Sphagnum fuscum	Sphagnum balticum	-	Sphagnum papillosum Sphagnum	Sphagnum fuscum Sphagnum	-

Sphagnum fuscum was studied in 1979-1988 at two mire sites located on the upper part of the ridges and on low flat hummocks (sites 1 and 3, respectively). Furthermore, the increment of *Sphagnum fuscum* was measured in 1984-1988 at site 1, that of *Andromeda polifolia - Sphagnum fuscum* in ridge slope microcenoses and that of *Eriophorum vaginatum- Sphagnum fuscum + Sphagnum balticum* at the ridge - hollow contact. Considerable increment was observed in *Sphagnum fuscum* in 1983, 1986, 1987 and 1988. In those years the growing seasons were humid, and precipitation was abnormally high, but the greatest annual increment was reported from all four sites in 1987 (Tables 1 and 3). In 1987, the amount of precipitation was quite sufficient in spring, autumn and even summer when plants grow actively. This contributed to the growth and development of *Sphagnum fuscum* at sites 1 and 3 (Table 3). Also, this may be due to the fact that its autumn growth period was longer than in other years (the growing season lasted 175 days). Lindholm (1990) has pointed out that the growth of *Sphagnum fuscum* is limited by a period of time with temperatures above 0°C during which growth rate depends on humidity. The substantial increment of *Sphagnum fuscum* at site 3, observed throughout the study period, is due to better environmental conditions and less appreciable variations in groundwater level that resulted from a large amount of water transported from the elevated mire margins. On the upper part of the ridge, the growth of *Sphagnum fuscum* slowed down markedly during extreme growing seasons (1979, 1980, 1985) when total precipitation was abnormally low. This is probably due to the fact that the capitula of *Sphagnum fuscum* were poorly supplied with water. Such a disturbance is indicated by the presence of dry capitula in the sod. Mosses grow more vigorously on ridge slopes and at the ridge-hollow contact because the sod is well provided with water in these habitats. Variability in the growth of *Sphagnum fuscum*, which forms various communities on ridge slopes and at the ridge-hollow contact, is presumably due to the effect exerted by the growth of one species on that of another. This seems to explain the fact that *Sphagnum fuscum* grows better at ridge slopes than at the ridge-hollow contact. *S. balticum* appears to suppress the growth of *S. fuscum*.

Table 3. Annual increment of *Sphagna*, mm/year

Site	Species	Microrelief	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1												
	Sphagnum fuscum	Upper part of the ridge	3	5	3	5	8	2	2	3	7	4
	Sphagnum fuscum	Slope of the ridge	-	-	-	-	-	9	9	10	17	15
	Sphagnum fuscum	Ridge-hollow contact zone	-	-	-	-	-	5	8	4	12	9
	Sphagnum balticum	Hollow	11	8	15	25	18	15	56	65	46	60
2												
	Sphagnum papillosum	Carpet	5	9	16	20	20	19	7	10	19	-
	Sphagnum majus	Carpet	46	38	57	50	35	22	54	24	59	-
3												
	Sphagnum fuscum	Hummock	6	9	6	6	8	7	3	66	15	9
	Sphagnum papillosum	Hummock	4	2	6	7	7	7	2	7	10	10

To sum up, the conclusion can be drawn that *Sphagnum fuscum* is not very susceptible to environmental changes and its increment varies only little in various microcenoses. The data obtained in the study area indicate that the linear growth of *Sphagnum fuscum* is closely related to weather during its growing season (coefficient of correlation (r) calculated for 1 and 3 mire sites are 0.46 and 0.56, respectively).

Sphagnum papillosum was investigated at sites 2 and 3. Considerable increment observed in *Sphagnum papillosum* at site 2 throughout the study period (Table 3), is due to the good flow and a more stable hydrological regime than at site 3, where groundwater level is more variable.

The increment of *Sphagnum papillosum* decreased in 1979, 1980 and 1985. This is due to the poor precipitation in the spring and during the entire growing season, as well as a shorter growing season. The maximum growth of *Sphagnum papillosum* was reported in 1987, when precipitation was very abundant and autumn growth was longer. Similar variations in annual increment were observed in *Sphagnum papillosum* growing in the mesotrophic hummock-hollow part of the mire (site 3), but here annual increment was much smaller. Site 2 has more favourable conditions for subpsychrophilic *Sphagnum papillosum* because this is not resistant to long drying often observed on fairly high hummocks at site 3 (coefficients of correlation (r) calculated for 2 and 3 mire sites are 0,35 and 0,82, respectively).

The increment of the hyperhydrophilic species *Sphagnum balticum* and *S. majus* was studied at wet sites 1 and 2, respectively. In dry years (1979, 1980,1985), variations in groundwater level observed in their habitats during their growing season were 4-15 and 4-7 cm below the *Sphagnum* surface, whereas in 1987 the water was at the moss capitula level. The variations in annual increment, observed in these hyperhydrophilic species, are similar to those of the previous species. This is probably due to some microclimatic characteristics of hollows and hummocks. Snow begins to melt earlier and goes off faster on hummocks, but their defrostation is slower. The microclimate of hollows is generally milder than that of hummocks which favours the growth of hollow species (coefficients of correlation (r) calculated for 1 and 2 mire sites are 0,49 and 0,21, respectively).

4 Conclusions

The studies revealed both large variations in linear growth of each moss species within one community in different years, and differences in growth during one growing season in communities different in their mineral nutrition and moisture.

The linear increment of *Sphagna* was found to ve closely related to the amount of precipitation during the growing season. Maximum increment of Sphagna was recorded in wetter years when recipitation was much higher than the average value for many years.

The growth of *Sphagna* is limited not only by the amount of precipitation but also by long exposure to temperature above 5°C.

Sphagnum fuscum is more tolerant to enviromental changes than the other species studied and its increment shows little variations in different microcenoses.

The linear growth of carpet subpsychrophilic and hyperhydrophilic *Sphagna* increases with a rise of ground water level.

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THE STRATEGY COMPARISON OF FOREST AND PEATLAND USE IN FINLAND

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1. Growth and storage

The carbon accumalation of the boreal peatlands is after Gorham (1991) on average 230 kg/ha/a . The amount is perhaps over-estimated, and for Finland a much lower figure of 110 kg C/ha/a is used here (cf. Tolonen et al. 1992). If the dry bulk density of peat is only 80 kg/m^3 (Tolonen & Ijäs 1990), the accretion rate is equivalent to 2.75 m^3 peat per hectare and to deposition of 0.28 mm/a. Calculated after the formula y (age) = 1 587 + 6.92x (depth) (Korhola 1992) the peat deposition in Southern Finland has been 0.63 mm/a.

The average depth of the Finnish peatlands was in the 1950´s – before the intensive forest drainage and other use – 106 cm (e.g. Eurola & Huttunen 1992). This is equivalent to 425 t C/ha. The net accumalation rate of the Finnish peatlands was at that time perhaps 1.1 Mt C/a.

The average volume of the Finnish forests is 80.7 m3/ ha and annual growth 3.4 m^3/ha (Yearbook...). If a cubic meter of timber is equivalent to 845 kg in total (Mälkönen 1974), there is 34 t C/ha in 68 t of organic matter. This can be calculated to be reached in 24 years (80.7 m^3/ 3.4 m^3). In addition, approximately 200 t C/ha has been accumalated in forest soils (Ahlholm & Silvola 1990 and references therein). The amount of carbon under peat deposits in mineral soil is unknown.

Peatland "needs" on average 310 years to reach a peat deposit equivalent to the carbon storage of forest stand. The productivity of forest is 13 times higher (310 a/ 24 a) than in mire. However, the circulation of the organic matter is in forest much more intensive than in mire. Thus the carbon storage of the Finnish peatlands was in the 1950´s 12.5 times higher than in the present tree stand (425 t C/ 34 t C), when calculated on an aerial basis per hectare.

2. User´s problems

Using a tree stand is simple as it does ot change the ecological basis of the forest biogeosystem. A new tree generation begins to grow after clear-cutting. With different management operations man also tries to stimulate tree growth which is nowadays on national basis higher than the drain. However, serious problems are connected with threatened species. These are dependent on rotten trees of old forests and on broadleaf stands. Forty-five percent of our threatened species are living in forests, five percent in peatlands (Rassi & Väisänen 1987).

The use of peat for any purpose cease the essential functions of the mire biogeosystem. We can totally use maintainably 0.03 % of the peatland area in a year, i.e. 2 600 ha. The same area should also be paludified annually. In practice the annual use is 2 550 times higher, i.e. 68 % (6.6 Mha) of the peatland area (Vapo 1989). In a virgin state this area would produce 0.73 Mt C/a as peat, equivalent to 1.7 Mm^3 timber. The average increase in annual production of our peatland forests is a cubic meter timber/ ha/a (Paavilainen & Tiihonen 1988), which sums up to 6 Mm^3/a in the drainage area of 5.9 Mha and 2.54 Mt C/a in the total tree stand. The figure is almost four times higher than the assumed peat production (0.65 Mt C/a) of the same area in its virgin state. Our peatland fields produce c. 0.15 Mt C/a (Ahlholm & Silvola 1991), and virgin peatlands (32 % of the mire area) 0.34 Mt C/a = 8.6 Mm^3 as peat. Our peat industry harvests 13-15 Mm^3/a (Ahlholm & Silvola 1990), which is almost two times more than our virgin peatlands produce. Furthermore, drained peatlands (peat fields, harvesting areas and peatland forests) are self-oxidized. This loss is difficult to estimate (cf. Ahlholm & Silvola 1991, Laine et al. 1994).

Our peat resources were in the 1950's 4 100 Mt C in 102.34 km^3 of peat. Nowadays the peat volume is 70.64 km^3 (Lappalainen ja Hänninen 1993). But the last figure is based only on geological mires (area > 20 ha, peat depth > 30 cm; total area 5.1 Mha).

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RARE AND PROTECTED VASCULAR PLANTS OF THE FLORA OF MIRES IN EASTERN FENNOSCANDIA

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1 Introduction

Eastern Fennoscandia includes Finland, Karelia, Murmansk region and adjacent areas of Leningrad region. It is one of the most paludified regions in the world. It has approximately 20 mill. ha of mires that are characterized by a great diversity of flora, vegetation and complex types.

The formation of the flora of eastern Fennoscandia after the glacial period resulted from the migration and further occurrence of species from different regions. Accordingly, many species now lie at the limit of their areals. Many of them have become rare at present. Different forms of the utilization of mires may cause their complete destruction and, consequently, there is an urgent need of evaluation of the entire diversity of the flora of mires, their types and the organization of the protection of mire ecosystems.

2 Results and discussion

The studies of the flora of mires in eastern Fennoscandia have shown that they include more than 300 species of vascular plants (Eurola et al. 1984, Kuznetsov 1989). Out of this number 283 species have been found on the mires of Karelia. 22 % (or 62 species) of them are regarded as rare in the whole republic or in some of its parts and therefore are in need of different forms of protection or biological control (Table 1). In the basic peatland protection programme worked out by Ministry of Agriculture and Forestry of Finland (Ministry of Agriculture and Forestry 1980) 61 vascular mire plants (20% of the mire flora of Finland) were regarded as threatened in the whole Finland or in some parts of it (Table 1).

The comparison of the lists of threatened species of mire plants of Karelia and Finland shows that there is much similarity between the two lists. 39 species can be found in both of them. Sörensen's coefficient of similarity between the two lists is 0.63. In my opinionsome species included into the Finnish list should not be considered as mire plants.

Table 1. Threatened vascular mire plants in Finland and Karelia
Fi – threatened in Finland (Ministry of Agriculture and Forestry 1980).
Ka – threatened in Karelia (Volkov & Lepschin 1985). 0 – no occurrence
o – occurrence in Karelia. s – southern part. n – northern part. a – all territory

N	Species	Fi	Ka	o	N	Species	Fi	Ka	o
1.	*Cystopteris montana*	+	+	n	44.	*Calypso bulbosa*		+	a
2.	*Dryopteris cristata*	+	+	s	45.	*Coeloglossum viride*		+	a
3.	*Thelypteris palustris*	+	+	s	46.	*Cypripedium calceolus*	+	+	a
4.	*Equisetum scirpoides*	+	+	a	47.	*Dactylorhiza traunsteineri*	+	+	a
5.	*E. variegatum*	+	+	n	48.	*D. baltica*		+	s
6.	*Lycopodiella inundata*		+	s	49.	*D. cruenta*	+	+	s
7.	*Selaginella selaginoides*	+			50.	*D. incarnata*	+	+	a
8.	*Triglochin maritima*	+			51.	*Epipactis palustris*	+	+	s
9.	*Bromus benekenii*	+			52.	*Hammarbya paludosa*	+	+	a
10.	*Catabrosa aquatica*	+			53.	*Liparis loeselii*		+	s
11.	*Eriophorum brachyantherum*	+	+	a	54.	*Listera ovata*	+		
12.	*Eriophorum latifolium*	+			55.	*Microstylis monophyllos*	+	+	s
13.	*Cladium mariscus*	+	0		56.	*Ophrys insectifera*		+	s
14.	*Eleocharis quinqueflora*	+	+	a	57.	*Salix reticulata*	+	+	n
15.	*Rhynchospora fusca*	+	+	a	58.	*S. pyrolifolia*	+	+	n
16.	*Schoenus ferrugineus*	+	+	a	59.	*S. repens*		+	s
17.	*Kobresia simpliciuscula*	+	0		60.	*Myrica gale*		+	s
18.	*Carex acutiformis*	+	+	s	61.	*Alnus glutinosa*	+		
19.	*C. appropinquata*	+	+	a	62.	*Betula humilis*	0	+	s
20.	*C. atherodes*	+	+	s	63.	*Stellaria calycantha*	+		
21.	*C. buxbaumii* subsp. *mutica*		+	n	64.	*S. crassifolia*	+		
22.	*C. buxbaumii* subsp. *buxbaumii*	+			65.	*S. uliginosa*		+	s
23.	*C. capillaris*	+			66.	*Thalictrum alpinum*	+	+	n
24.	*C. capitata*	+	+	a	67.	*Ranunculus lapponicus*	+	+	n
25.	*C. disticha*		+	s	68.	*Cardamine flexuosa*	+	0	
26.	*C. glacialis*		+	n	69.	*Drosera intermedia*	+	+	s
27.	*C. heleonastes*	+	+	a	70.	*Saxifraga hirculus*	+	+	a
28.	*C. laxa*	+	+	n	71.	*S. aizoides*	+	+	n
29.	*C. lepidocarpa* var. *jemtlandica*	+	+	n	72.	*Sanguisorba polygama*	0	+	n
30.	*C. livida*	+	+	n	73.	*Viola uliginosa*	+	0	
31.	*C. norvegica* subsp. *inferalpina*		+	n	74.	*Epilobium alsinifolium*	+	+	n
32.	*C. paniculata*	+	0		75.	*E. hornemannii*	+	+	n
33.	*C. parallela*		+	n	76.	*E. davuricum*	+	+	n
34.	*C. pseudocyperus*	+	+	s	77.	*Angelica archangelica*	+	+	n
35.	*C. recta*	0	+	n	78.	*Erica tetralix*	+	0	
36.	*C. riparia*		+	s	79.	*Lycopus europaeus*		+	s
37.	*C. tenuiflora*	+	+	a	80.	*Pinguicula alpina*	+	+	n
38.	*C. viridula*		+	a	81.	*P. villosa*		+	n
39.	*C. vulpina*		+	s	82.	*P. vulgaris*	+		
40.	*Juncus stygius*	+			83.	*Galium odoratum*	+		
41.	*J. triglumis*	+	+	n	84.	*Ligularia sibirica*	0	+	s
42.	*Tofieldia pusilla*	+			85.	*Petasites frigidus*	+		
43.	*Iris pseudacorus*		+	s		Total	61	62	

From the 1960s on, the problems of the preservation of the diversity of the flora and fauna were paid greater attention. It resulted in establishing national parks and nature reserves. Steps have been taken to make lists of rare and threatened species to estimate the state of the flora and fauna. Later on, Red Books were composed on the basis of those lists. They ranged from the Red Books of separate regions to the Red Book of the world. Red Books include information on the biology and occurrence of every enlisted species as well as some recommendations concerning possible ways of their protection. Including species in Red Books of different levels is only the first stage for their protection. Nowadays, occurrence of endangered species is the most important basis for establishing nature conservation areas of different status.

The conservation of threatened mire species in eastern Fennoscandia is of great interest to us. The latest edition of the Red Book of Finland (Rassi et al. 1991) includes 21 species of vascular plants that occur on different types of mires. It also includes 14 species that occur on mires and other sites (Table 2). Only 15 species of this total of 35 have been included in the list of threatened species of mires, that was made up in 1980 by ministry of agriculture and forestry of Finland (Table 1). So it is evident that not all species of mire flora in need of protection have been included into the Red Book of Finland.

The acts of 1976 and 1979 of the Karelian government made provisions for the protection of all species of the family *Orchidacae* and 50 species of wild decorative plants. Some of them are mire plants. The Red Book of Karelia, published in 1985, included 160 species of vascular plants, of this total 31 being mire species or species which occur on mires (Table 2). The comparison of the list of threatened plants of mires of Karelia (Table 1) with the list of mire plants included in the Red Books of Russia (1988) and Karelia (Table 2), has shown that only 23 species (37%) of the total have been included into these Red Books.

Attempts were made to compare the lists of mire species in the Red Book of Finland (Rassi et al. 1991) and the Red Book of Karelia (Table 2). The difference is evident. Though the total of vascular mire plants is 57, only 9 of this total are included in both books (*Botrychium virginianum*, *Calypso bulbosa*, *Cypripedium calceolus*, *Dactylorhiza cruenta*, *D. traunsteineri*, *Epipactis palustris*, *Microstylis monophyllos*, *Ophrys insectifera*, *Salix pyrolifolia*). The coefficient of similarity is only 0.27. Though the flora of Finland and Karelia are very similar (Hämet-Ahti et al. 1986, Ramenskaya 1983), and there is also much similarity between their mire floras (Eurola et al. 1984, Kuznetsov 1989), the difference in the lists of protected species reveals a different methodological approach to compiling lists and a further need of joint studies on these problems.

The Red Book of the Murmansk region (Redkie... 1990) comprises 32 species of vascular mire plants (Table 2). 17 of them are included also in the Red Book of Karelia (coefficient of similarity is 0.53). Only 4 species can be found in the Red Book of Finland (*Calypso bulbosa*, *Cypripedium calceolus*, *Dactylorhiza traunsteineri*, *Schoenus ferrugineus*) – coefficient of similarity is only 0.12.

Table 2. Protected vascular mire plants of eastern Fennoscandia.

Ru – Russia Ka – Karelia Mu – Murmansk region (Andreev & Makarova 1990) Fi – Finland

0 – no occurrence D – disappeared E – endangered V – vulnerable
M – needs monitoring Md – declining Mr – rare Mp – poorly known
R – rare I – indeterminate

N	Species	Ru	Ka	Mu	Fi	N	Species	Ru	Ka	Mu	Fi
1.	*Blechnum spicant*	-	0	0	D	38.	*D. incarnata*	-	+	R	-
2.	*Equisetum scirpoides*	-	+	R	-	39.	*D. fuchsii*	-	+	-	-
3.	*E. variegatum*	-	+	-	-	40.	*D. lapponica*	-	0	-	Mp
4.	*E. trachyodon*	-	0	0	Mr	41.	*D. maculata*	-	+	I	-
5.	*Botrychium virginianum*	-	+	0	V	42.	*D. traunsteineri*	V	+	I	Md
6.	*Arctagrostis latifolia*	-	0	-	Mr	43.	*Epipactis palustris*	-	+	0	Md
7.	*Eriophorum brachyantherum*	-	-	R	-	44.	*Gymnadenia conopsea*	-	+	I	-
8.	*Rhynchospora fusca*	R	+	0	-	45.	*Hammarbya paludosa*	-	+	R	-
9.	*R. alba*	-	-	R	-	46.	*Herminium monorchis*	-	0	0	D
10.	*Cladium mariscus*	R	0	0	V	47.	*Liparis loeselii*	R	-	0	E
11.	*Schoenus ferrugineus*	-	-	R	Md	48.	*Listera cordata*	-	+	-	-
12.	*Carex atherodes*	-	-	0	Mr	49.	*L. ovata*	-	+	R	-
13.	*C. disperma*	-	-	R	-	50.	*Microstylis monophyllos*	-	+	0	V
14.	*C. heleonastes*	-	-	-	Md	51.	*Ophrys insectifera*	V	+	0	E
15.	*C. hostiana*	0	0	0	Md	52.	*Salix myrsinites*	-	+	-	-
16.	*C. lapponica*	-	0	R	-	53.	*S. pyrolifolia*	-	+	-	E
17.	*C. laxa*	R	-	R	-	54.	*S. repens*	-	+	E	-
18.	*C. lepidocarpa* var. *lepidocarpa*	-	0	0	V	55.	*Myrica gale*	V	+	0	-
19.	*C. lepidocarpa* var. *jemtlandica*	-	-	0	Md	56.	*Alnus glutinosa*	-	+	0	-
20.	*C. livida*	R	-	R	-	57.	*Stellaria fennica*	-	-	-	Mr
21.	*C. microglochin*	-	0	-	Md	58.	*Cardamine flexuosa*	-	0	0	E
22.	*C. otrubae*	-	-	0	V	59.	*Saxifraga hirculus*	-	-	-	Md
23.	*C. remota*	-	0	0	V	60.	*Chrysosplenium alternifolium*	-	-	R	-
24.	*C. riparia*	-	-	0	Mr	61.	*C. tetrandrum*	-	-	R	-
25.	*C. rhynchophysa*	-	-	R	-	62.	*Lathyrus palustris*	-	-	R	-
26.	*C. stenolepis*	-	-	R	-	63.	*Viola uliginosa*	-	0	0	V
27.	*C. tenuiflora*	-	-	R	-	64.	*Epilobium alsinifolium*	-	+	R	-
28.	*C. vulpina*	-	-	0	V	65.	*E. davuricum*	-	+	R	-
29.	*C. viridula* var. *bergrothii*	-	-	-	Md	66.	*E. laestadii*	-	0	0	V
30.	*Calla palustris*	-	-	R	-	67.	*Erica tetralix*	0	0	0	E
31.	*Iris pseudacorus*	-	+	0	-	68.	*Chamaedaphne calyculata*	-	-	R	-
32.	*Calypso bulbosa*	R	+	R	Md	69.	*Peucedanum palustre*	-	-	R	-
33.	*Corallorhiza trifida*	-	+	R	-	70.	*Primula farinosa*	-	0	0	Md
34.	*Coeloglossum viride*	-	+	-	-	71.	*Bartsia alpina*	-	+	-	-
35.	*Cypripedium calceolus*	R	+	E	Md	72.	*Pinguicula villosa*	-	+	R	-
36.	*Dactylorhiza baltica*	V	+	R	-	73.	*Ligularia sibirica*	-	-	R	-
37.	*D. cruenta*	-	+	0							0

At present preparations for the publication of a new Red Book of Karelia are being made on the basis of some basic studies on the flora of Karelia and all Fennoscandia (Hulten 1971, Atlas...1972, Ramenskaya 1983, Hämet-Ahti et al. 1986, Rassi et al. 1991), numerous archive and herbarium materials and new scientific data. We also plan to include data of flora and occurrence of species in regions adjacent to Karelia (Leningrad, Murmansk, Archangelsk and Vologda regions). We think it necessary to define categories of species in the next publication in accordance with IUCN principles, which was not made in the previous work.

Researchers of Finland, Karelia and St. Peterburg have put forward the idea about the necessity of work on a Red Book of the entire eastern Fennoscandia. This idea was approved by the Ministry of Environment of Finland and the Ministry ef Ecology of Karelia. This project will provide an excellent opportunity for accumulating data on the flora and fauna of this particular region. Mires in this region are regarded significant ecosystems. Therefore a better study of their flora and fauna will become the basis for an extensive system of their protection in Fennoscandia.

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THE CURRENT STATE OF MIRES IN THE RAISED BOG ZONE OF FINLAND

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1 INTRODUCTION

The draining of mires in Finland for forestry purposes is 20 times more extensive than the world average, and draining for agriculture and use for conservation 7 times more extensive (Eurola 1990). Due to this intensive use of mires, a need on inventory arose, the results of which are now available (eg. Eurola et al. 1988, 1991). Apart from the question of how well the drained areas are suited economically and ecologically for forestry, there is that of how well the protected sites represent the mire site types and mire flora and guarantee their protection.

2 METHODS

154 random sample plots, each 1 x 1 km in area (732 km line) form the data source for an inventory of peatlands in both a virgin and a drained state, together with a further 94 randomly chosen plots of size 0.5 x 0.5 km (238 km line) in planned conservation areas, studied in order to estimate the representation of the mire site types and mire plants of the raised bog zone. A line transect method was used, the distance between the transects being 50 m. The virgin mire vegetation was investigated and allocated to 56 mire site types.

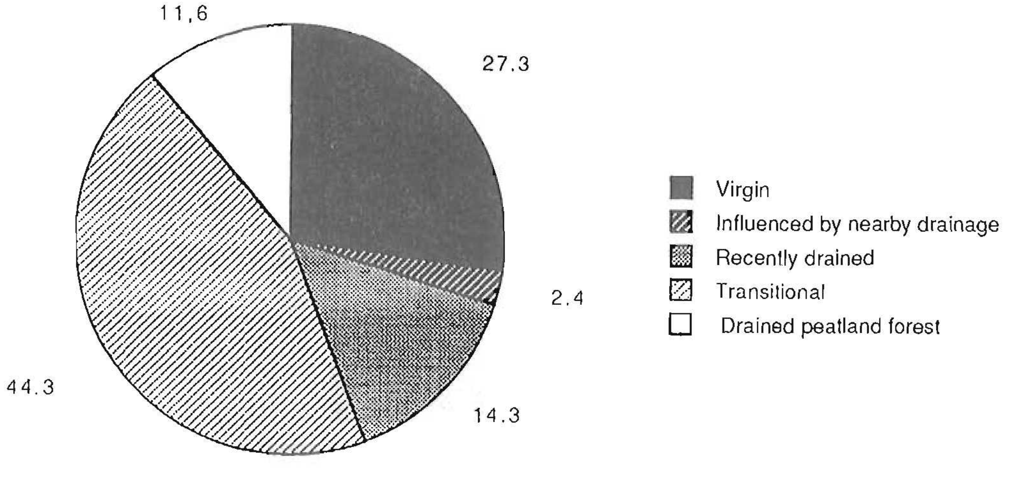

Fig. 1. State of drainage of the peatlands in the bog area.

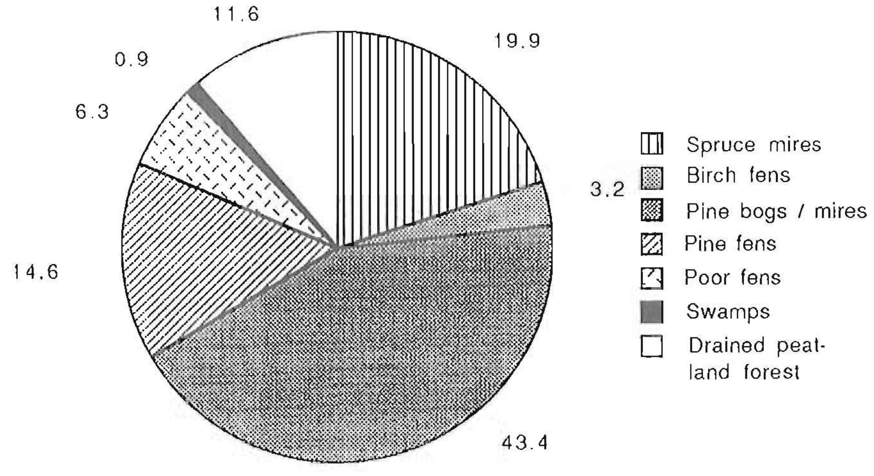

Fig. 2. Percentages of the main mire type groups in the bog area.

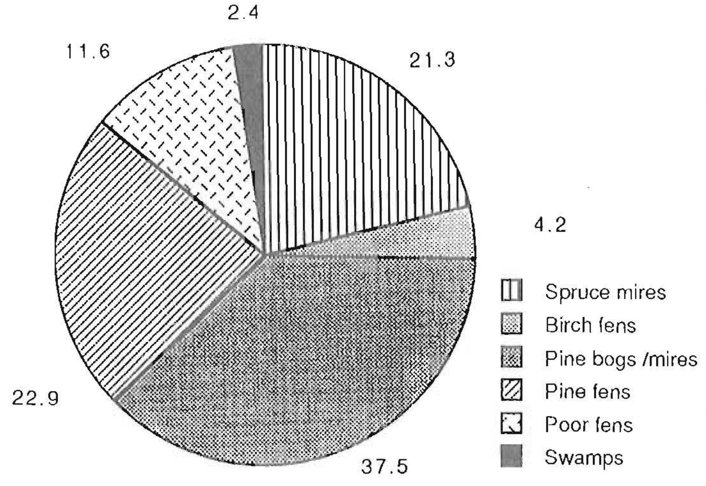

Fig. 3. Percentages of the main mire type groups in the virgin area.

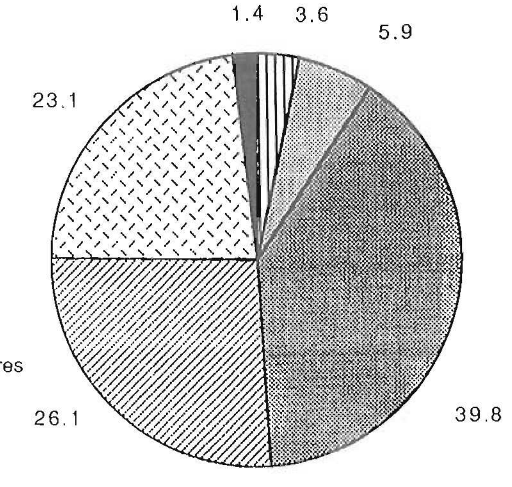

Fig. 4. Percentages of the main mire type groups in the protected area.

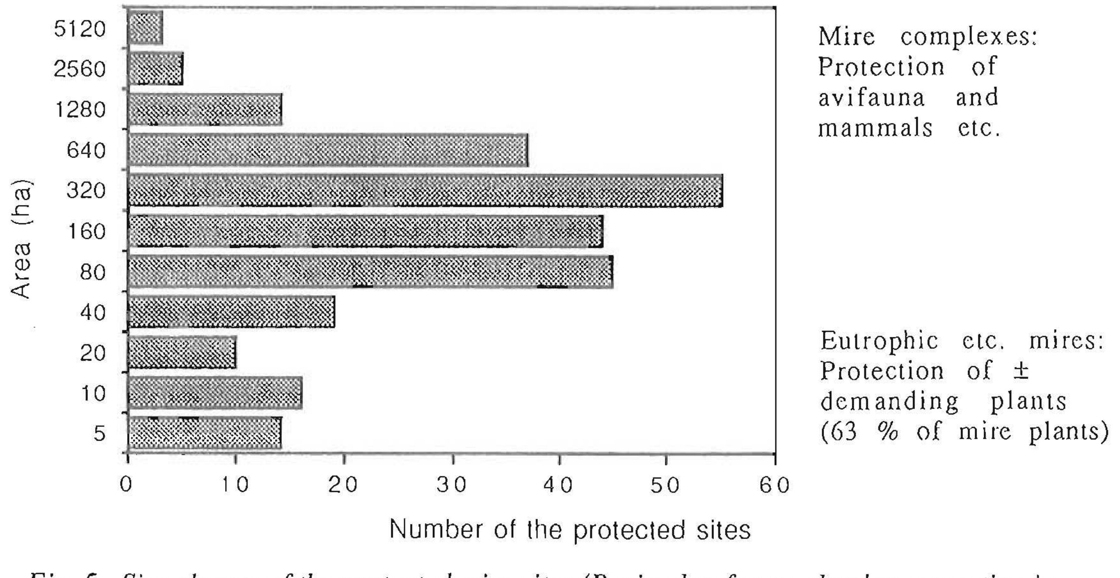

Fig. 5. Size classes of the protected mire sites (Basic plan for peatland preservation in Finland 1981, Eurola 1990).

3 RESULTS AND DISCUSSION

56 % of the mire site types in the raised bog zone which are unfit for forestry have been drained, 12 % of this drainage being unnecessary (Eurola et al. 1988, 1991). As a result, only 27 % of the peatlands in the zone are in a virgin state (Fig. 1). 61 % of the drained mires are in the transitional phase and 12 % in the final succession phase (drained peatland forests).

The proportions of the main mire type groups are clearly different in the total, virgin and protected mire areas of the zone (Figs. 2-4). Rich fens and spring vegetation types cover less than one thousandth of these three area categories. The virgin mire vegetation in the bog zone has become greatly impoverished and more wooded over the last 30 years or so (from the 1950's to the 1980's). The proportion of ombrotrophic *Sphagnum fuscum* bogs and combination types of the same nutrient status within the virgin mires has increased about four-fold (Eurola et al. 1988, 1991).

The wooded mire sites have mostly been drained, including two-thirds of the spruce mires and many pine bogs and their combinations. Similarly, a half of the poor fens and more than two-thirds of the rich fens are influenced by drainage. On the other hand, three-quarters of the swamp and spring vegetation is in a virgin state (Eurola et al. 1988, 1991). All the ten most common mire site types (Table 1) are nowadays wooded, whereas the proportion of open fens was still 11 % in the 1950's (Ilvessalo 1956). Thus drainage has led to an overemphasis on hummock-level development.

Some of the thin-peat paludified forests seem to have changed to a forest vegetation due to drainage. The most common mire site type nowadays is the tall shrub pine bog, while *Sphagnum fuscum* hollow bogs predominate among the virgin mires. One important result regarding the ecology of the ecosystems was that, in contrast to the aapa mire zone, the mires under an inherent effect have been drained to a greater extent than those with a mire margin effect. The differences in virgin vegetation between the raised bog and aapa mire zones have become more acute during the last 30 years.

The proportion of small scale protection sites is still low (Eurola 1990), and these sites represent mainly the protection of demanding plants and habitats (Fig. 5). The high proportion of large protection sites means in practice that common mire types and also complexes are quite well protected.

Implementation of the planned mire protection sites is still some way off, and a proportion (21.1 %) of them have already been drained. Spruce mires, eutrophic mires, springs and seepage mires in particular (among the rare and endangered mire site types, which make up less than one pro mille of the virgin mire area) are underrepresented among the protected mire sites, and more effort is needed to preserve eutrophic plant species (see Anon. 1992). The next basic plan for peatland preservation in Finland (see Heikkilä et al. 1992) is going to improve the current situation especially on this field.

Table 1. Percentages of the ten most common mire site types, counted from each category separately.

	Bog area	Virgin	Protected
Ordinary dwarf shrub pine bog	16.9	10.0	13.6
Eriophorum vaginatum pine bog	8.9	8.9	17.0
Vaccinium myrtillus spruce mire	6.3	5.9	
Drained *Vaccinium myrtillus* peatland forest	6.1		
Sphagnum fuscum hollow bog	5.0	11.5	17.3
Herb/grass birch-spruce mires	4.7	5.2	
Calluna-Sphagnum fuscum bog	4.5	4.6	
Ordinary tall-sedge pine fen	3.6	5.9	4.6
Equisetum sylvaticum spruce mire	3.3	4.0	
Ordinary spruce-pine mire	3.2		
Empetrum-Sphagnum fuscum bog		4.4	2.6
Thin-peated spruce mire		4.0	
Ordinary short sedge fen			5.4
Ombrotrophic short-sedge bog			4.4
Ordinary short-sedge pine fen			4.2
Ombrotrophic hollow bog			3.1
Ordinary tall-sedge birch fen			2.6

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UNPROTECTED MIRES WITH CONSERVATION VALUE IN FINLAND

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1 Introduction

1.1 History of mire conservation in Finland

Kujala (1939) was the first to raise up the question of mire conservation in Finland. The first mires to be protected in Finland were presented in the end of 1940s when the Finnish Nature Conservation Association suggested the establishment of new national parks and strict nature reserves. As a consequence of the suggestion, a committee for national parks started its work. On the basis of it, strict nature reserves of Vaskijärvi, Häädetkeidas, Runkaus and Sompio were established in 1956, especially to protect good examples of raised bogs and aapamires for scientific purposes. In addition, valuable mires were included in several other national parks and strict nature reserves, e.g. Oulanka and Salamanperä.

Rich fens and fertile spruce mires were found to have decreased due to agriculture and forestry, and their protection was considered to be important to protect the diversity of plants (Kujala 1939, Keltikangas 1955). Isoviita (1955) was the first to pay attention to the disappearing of virgin raised bogs, and to emphasize the protection of them.

The first mire conservation plans were made in the 1960s when forestry drainage of mires expanded enormously. The plans covered c. 180 000 ha of state-owned mires, mainly large mire complexes in northern Finland (Häyrinen & Ruuhijärvi 1966, 1969). During the work it became clear that especially in southern Finland also privately owned mires must be protected to ensure the protection of mire ecosystems. On the basis of the plans, the Forest and Park Service of Finland protected most of the mires on its own decision. Later, in the 1970s, many of these decisions were canceled, and the mires were given to peat extraction, on the basis of a compromise between the ministry of agriculture and forestry (which was responsible of nature conservation at that time), and the ministry of trade and industry.

In the 1970s a plan for the development of the network of national parks and strict nature reserves including many of the most valuable mires was prepared (Tallgren et al. 1976:88), and at the same time a nationwide mire conservation programme was compiled (Haapanen et al. 1977, Haapanen et al. 1980, Ministry of agriculture and forestry 1981, Ruuhijärvi 1978, Salminen 1978). In these programmes, the goals were to preserve the diversity of mire complexes, mire site types, vascular plants and birds as well as to form a comprehensive network of reserves. The main goal was to protect typical and large examples of mire complex types, but attention was also paid to small mires, especially rich fens which were valuable for the conservation of mire flora. A system to assess the conservation value of rich fens was developed (Kaakinen & Kukko-oja 1981). The first lists of threatened mire site types and vascular plants in mires were compiled (Ruuhijärvi 1978, Haapanen et al. 1980). The mire conservation programme consisted of 600 mires covering altogether c. 500 000 ha. The mean size of mires proposed for protection was almost 1000 ha.

1.2 Present situation of mire conservation in Finland

So far, 173 mires, which belonged to the mire conservation programme, covering altogether 414 000 ha, have been protected by law (Hokkanen 1994). Thus 80% of the area of the mires belonging to the programme have been protected, but only 35% of the number of the mires. In addition, almost 400 000 ha of mires are included in national parks, strict nature reserves and wilderness areas (Aapala et al. 1995). Most of the mires not yet protected are small privately owned areas. The state has not been able to buy them for conservation because of the lack of money and personnel.

The need for a complementary mire conservation programme became evident in the 1980s for many reasons:

During the 1980s about 50 000 ha of the mires belonging to the programme have been drained by the private landowners. In some cases these activities have been well organized. For example, Talasneva mire, a raised bog with a fine pool-ridge complex covering c. 120 ha, was drained during one night by all the owners of the mire using eight excavators.

Outside the nature reserves, most of the mires up to southern Lapland have been drained. In addition to those suitable for timber growth, also a large number of too poor mires have been drained (R. Heikkilä 1984, Eurola et al. 1991). Every mire complex has been drained at least partly.

The assesment of threatened plant and animal species in the 1980s produced a lot of new information about the need for nature conservation (Rassi et al. 1992). In addition to the classification of species in different groups (extinct, endangered, vulnerable, in need of monitoring) in whole country, an assesment on the provincial level was made for the best known groups of flora and fauna. In whole Finland, c. 5% of threatened vascular plant species are devoted to mires, but in all the provinces of the southern half of Finland the proportion is about 30%, due to the intensive use of mires for forestry and agriculture (Rassi et al. 1992, Fig. 1).

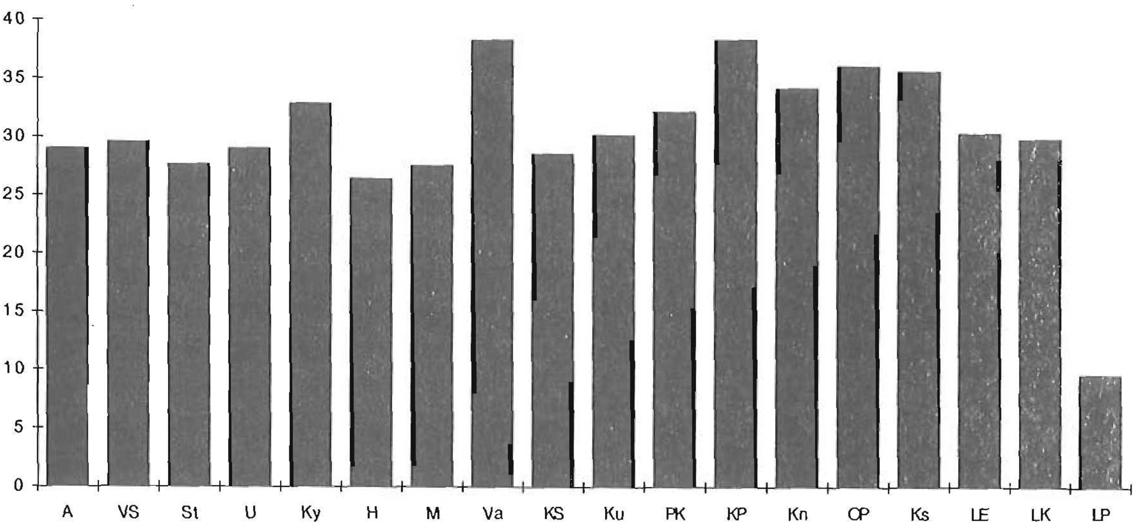

Fig. 1. The percentage of mire plants of the threatened vascular plant species in different provinces of Finland from Aland in the south (A) to northern Lapland (LP). Drainage of mires has been a major factor threatening the diversity of vascular plants in all the provinces but northern Lapland. In country level the proportion of mire plants of threatened vascular plants is 9.3%.

In the 1980s, thorough studies about the vegetation of rich fens in southern Finland (H. Heikkilä 1987, 1991, 1992) as well as studies about the distribution of virgin and drained mire site types (Eurola et al. 1991) were made. When the results of Eurola et al. (1991) and those of a comprehensive forest inventory in the early 1950s (Ilvessalo 1956) were compared, it showed up that 95% of rich fens were drained during 35 years. A study about the distribution of mire site types in nature reserves (Hanhela & Suikki 1993) produced new information about the success of mire conservation. Also studies about threatened mire plants (R. Heikkilä 1990, 1992) added to the knowledge of the state of the Finnish mires. On the basis of the above mentioned the ministry of the environment initiated research in the National Board of Waters and Environment about the needs and possibilities to prepare a complementary mire conservation programme in October 1990.

2 The goals of complementary mire conservation

2.1 The protection of mosaics of forests and mires not forming mire complexes

In the National Mire Protection Programme (NMPP) the main aim was to protect wide mire complexes, raised bogs and aapamires. Less attention was paid to small-scale mosaics of forests and mires not forming mire complexes being only narrow strips of spruce mires or pine swamps between hills of mineral soil. Thus thin-peated mire sites, ecotones of mires and forests, and small swamps and spring fens are not adequately protected. In many respects the ecotones of mires and forests are hot spots in the species diversity of vegetation (Tolvanen 1994), birds, epiphytic lichens, bracket fungi and insects in the Finnish nature.

Seasonally wet treeless and almost peatless hollows with a very special vegetation are rare biotopes of large glaciofluvial formations. Very few of those have been included in the present reserves.

2.2 The protection of the succession of land upheaval coast

In the coast of the Bothnian Bay the terrain is very flat, and the maximum land upheaval is c. 9 mm/year, thus 90 cm in a century. Therefore, new land is continuously released from the sea, partly directly paludifying. In the progress of land upheaval a series of mires, different in age, has been formed. In some cases, in a limited area a successional series covering many thousands of years, has been formed from initial stages of mires up to mature complexes, eccentric bogs or plain aapamires. This is a unique phenomenon in the world, excluding arctic Canada,where climatic circumstances are totally different. The successional series of the mires in the Bothnian Bay coast is a globally unique feature which is, so far, not protected in large areas and uniform time series. Therefore Finland has a global responsibility of protecting the features connected with land upheaval succession, and the protection of the last remained succession series in Hailuoto and Siikajoki is specially important.

2.3 The protection of sloping fens

So far, it has been known that in some hill areas in Kainuu and Kuusamo provinces of Finland as well as parts of Lapland there are good examples of sloping fens which are valuable for protection. Lately it has been found out that aslo in some elevated areas of southern and middle Finland there are locally sloping fens, e.g. in Alkkianvuori hill in Karvia and in Talaskangas in Vieremä. Because of geographical reasons it is very important to protect also the deviations of the main distribution area of sloping fens.

2.4 The protection of mire complexes

While maps and aerial photographs have become better, and after additional field inventories, some earlier unknown valuable mire complexes have been found. It is important to protect them especially in regions where there are not many earlier protected mires, or where the utilization of mires has been especially intensive. This is the case e.g. in the province of Oulu where there are plans to widen the use of fuel peat. Also forestry drainage of aapamires has been very intensive there.

2.5 Re-evaluation of the boundaries of protected mires

So far, a major problem in mire conservation has been that earlier it was not possible to include any buffer zones on mineral soil in the reserves. In very many cases also the thin-peated ecotones between mires and forests have been left outside the reserves. Earlier it was also possible to cut the mineral soil forests inside the mire reserves. Luckily, the Forest and Park Service decided in 1994 to end forestry in mire reserves.

A re-evaluation of the boundaries of mire reserves should be made to such an extent that no land use outside the reserves would influence the protected nature in the reserves. Except as buffer zones the ecotones between mires and forests are also important for species diversity. Therefore the goal should be to protect mires, forests and watercourses together as nature reserves, and not to protect mires separately as mire reserves. E.g. in the Republic of Karelia the principle in mire conservation is to include at least 200 metres wide buffer zones on mineral soil around the mires in the reserves (A. Shirlin, pers. comm. 1993).

2.6 Improvement of the network of mire reserves

Mire conservation so far is spatially not in balance: mire reserves are mainly situated in Suomenselkä and Maanselkä water divides and in Northern Finland (Aapala et al. 1995). Especially in southeastern Finland and the lake district of Middle Finland there are very few protected mires. In Southern Finland there are large areas where more than 90% of mires have been drained. Therefore special attention in the inventories has been paid to the abovementioned regions. In these areas the criteria for choosing mires to be protected must not be as strict as elsewhere.

3 Restoration of mires

Because many mires belonging to the NMPP have been drained, and there are also many drained mires in the present reserves (Aapala et al. 1995), efforts and experiments of the restoration of drained mires have been started (Seppä et al. 1993, Heikkilä & Lindholm 1994). The aim is to restore the water balance of mires so that they turn to peat-producing ecosystems again. Cutting of timber grown as a consequence of the drainage is also important to restore the landscape mosaic of mires and forests (Heikkilä & Lindholm 1994). In some cases some new mires for protection are suggested, if e.g. their threatened flora has still survived after the drainage.

4 Additional mires to be protected - choosing and classifying

Additional mires to be protected have been searched along the 1980s using new topographic maps and aerial photographs as well as intensive field studies. The southern half of Finland has been studied especially in connection with Hanna Heikkilä's studies of rich fen vegetation. In different parts of the country thorough inventories of threatened species have been made on provincial level. This data has veen completed with a questionnaire to different experts and organisations in the autumn 1990.

All virgin mires with threatened mire site types (Table 1) or species (Rassi et al. 1992) have been regarded as valuable for conservation. Also more or less virgin typical mire complexes with no threatened site types or species must be regarded as valuable for conservation especially in regions with a sparse network of protected mires, or where mire utilization has been especially intensive.

In this study mires have been divided into three categories: To class I belong well studied mires which are clearly valuable for conservation. In class II there are mires which probably are valuable, but about which the knowledge is incomplete. Studied mires with no special conservation value belong to class III.

A list of mires belonging to classes I and II with detailed descriptions and maps has been compiled (R. Heikkilä 1995). There are altogether 520 mires in the list, covering altogether c. 120 000 ha. The mean area of the mires proposed to be protected is thus much smaller than in the NMPP (Fig. 2). Most of the mires, especially in class I, are small fragments of rich fens or fertile spruce mires. There are also some large mire complexes, and a few large areas of mosaics of mires and forests, covering up to 6000 ha. It is suggested that most of the small mires could be protected as key biotopes in connection with forestry planning, but it is recommended that the larger mire complexes should be protected as nature reserves.

Table 1. Threatened mire site types in Finland. Compiled on the basis of Ruuhijärvi (1978) and Eurola et al. (1991). Abbreviations of site types after Eurola et al. (1984). Southern Finland has been limited along the southern margin of the zone of aapamires of Forest-Lapland (Ruuhijärvi 1988).

Site type	Raised bog zone	Southern Finland	Aapa zone	Whole Finland
LhK				x
SaK				x
RhMK			x	
LäRhK				x
LuRhK	x			
LK		x		
NigNK			x	
KaNR	x			
RiNR	x			
RhSN	x			
RhKaN	x			
LR		x		
LuL				x
LäL				x
VL				x
KoL				x
RiL		x		
LN		x		
AlnLu				x
KoLu			x	
PaLu		x		
Tihkup.				x
MeLä				x
MeEuLä				x
EuLä				x
KeR			x	
KuN			x	

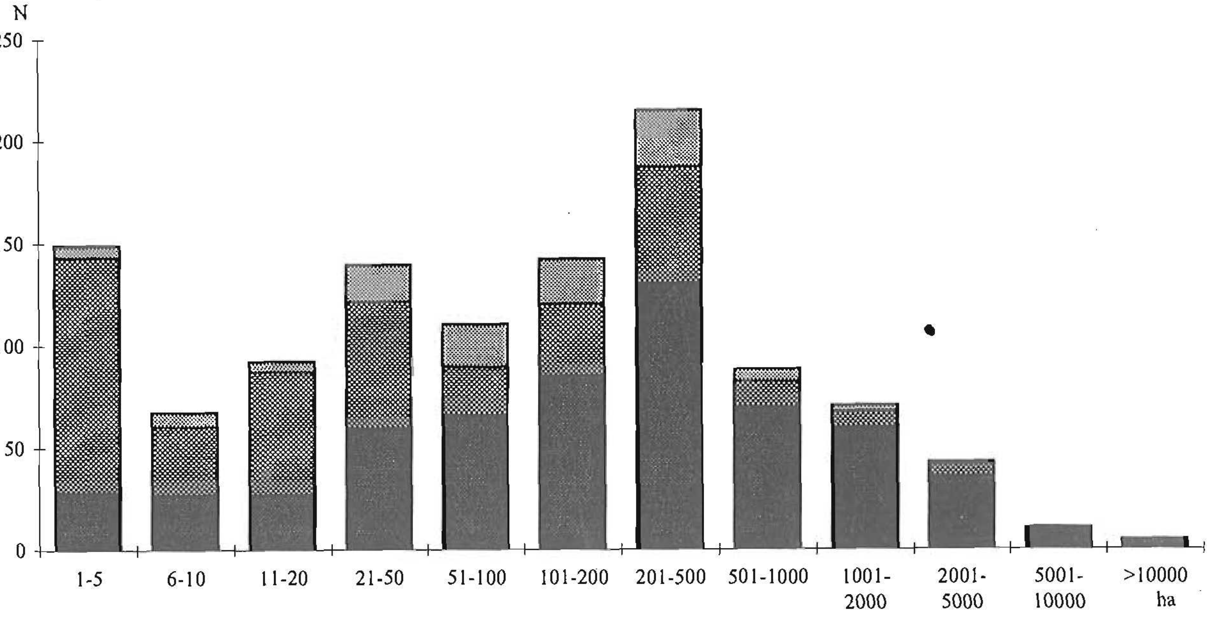

Fig. 2. The size distribution of mires in the NMPP (dark) and in categories I (shaded) and II (grey) in the proposal of additional mires to be protected.

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MIRES OF SEITSEMINEN- HOW TO MAKE A NATIONAL PARK

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1 Introduction

About 1/3 of Finland has been covered with mires, e.g. 10.4 million ha (Lappalainen & Hänninen 1993). They were used for agriculture and other purposes for centuries, but they did not widely suffer long-term changes. Only during this century mires were turned into arable fields in large scale (Heikkilä 1989). The most drastic changes were caused, however, by forestry. The drainage of mires for better tree growth begun in the beginning of 20th century (Päivänen 1990). The main occupation happened in 1960s and 1970s, when 60 % of Finnish mires were drained for forestry.

This happened also in the area of the nowaday national park Seitseminen in western Finland. Its virgin mires and forests formed once an invaluable mosaic-like landscape, even if they were not floristically very interesting. Now the forests are cultivated and most of the mires are drained. This is regarded as unsuitable in the national park (Helminen 1988, Metsähallitus 1993). So restoration plans for both elements, mires and forests, are necessary.

In the Seitseminen national park there are 1 200 ha of drained mires, most of which will be restored. In this article the basics of the restoration as well as methods, goals and preliminary results are discussed.

2 Study area

The national park of Seitseminen is situated in the southern Suomenselkä water divide area (Fig. 1), which is slightly above the surroundings. Therefore there is a little more moisture than in the areas around: mean precipitation, 40% of which comes as snow, is 719 mm (Finnish meteorological institute 1994). The annual evapotranspiration varies between 325 and 350 mm (Solantie 1988). The bedrock and soil are acidic and poor in nutrients. Along some eskers in the national park there are a few softwater springs, but their influence in the vegetation is very limited. According to the Finnish zonation of mire vegetation (Ruuhijärvi 1983, 1988), Seitseminen lies in the region of inland eccentric bogs (Fig. 1).

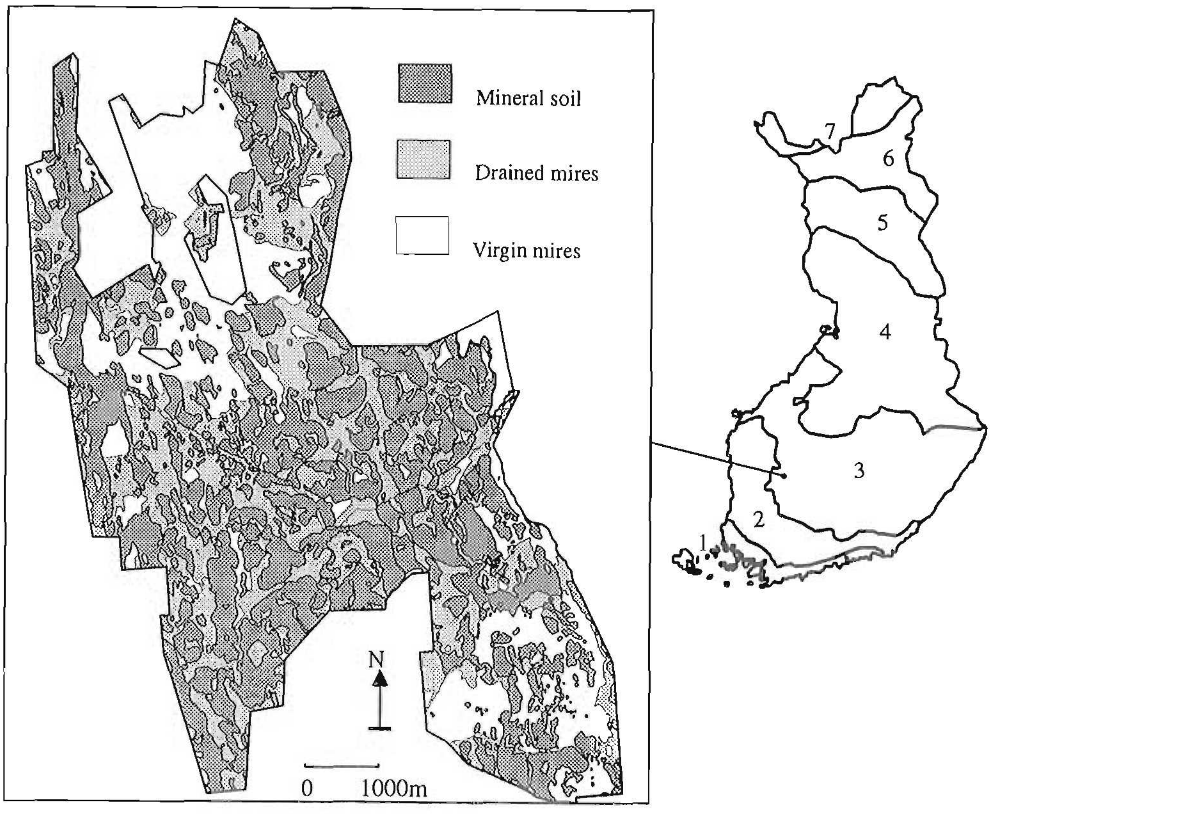

Fig. 1. Location of the Seitseminen national park and its current drainage situation. 1 – Plateau bogs. 2 – Concentric bogs. 3 – Eccentric bogs. 4 – Southern aapa mires. 5 – Main aapa mires. 6 – Northern aapa mires. 7 – Palsa mires and orohemiarctic mires.

About half of the national park is covered by peat soils. Poor ombrotrophic and oligotrophic mire sites dominate. Mesotrophic mires cover only a few hectares, and no rich fens are found. Virgin mires are mainly small ombrotrophic bogs with no clear hummock-hollow structure (Leivo et al. 1989). According to old aerial photographs from the years 1930 and 1963, the drained mires have been quite different. Most of them have been wet, more or less open minerotrophic fens. Most of the spruce mires have been drained, and only some paludified spruce forests are intact. On the basis of the information from forestry inventories, the drained spruce mires have had a thicker peat layer than today's virgin spruce mires. Their vegetation has been dominated by *Vaccinium myrtillus* and *Equisetum sylvaticum.*

3 Changes in vegetation - management and succession

The past management of the mires of Seitseminen was deducted from aerial photos from the years 1930, 1963 and 1991. The amount and situation of ditches was surveyed. The tree cover of mires in different times was estimated.

In 1930 the mires of the area were almost totally in a virgin state. There were only two drainage areas. Here and there were solitary ditches which had been dug in order to keep roads dry or to lower lakes and ponds. All ditches were made by spade.

In 1963 there were much more ditches. Still large areas were in a natural state. Most of the 1930-1963 ditchings were made in the margins of mineral soils. They were made to prevent supposed mire expansion to the forests. These ditches were quite old in 1963. The drainage by machines had begun in the late 1950s and there were some new drainage areas in Seitseminen in 1963.

Most of the drainage was done in a relatively short time, between 1965 and 1972. Drainage was extensive and even the smallest strips and patches were united to the network of ditches, excavated through mineral soils. The ditches were dug by excavators, several of which were in use. Drainage was done even in winter. The mires were drained effectively with ditches 30 m or less apart. Ditches were usually also dug to the margin of mineral soil.

This drainage system overlayed former ditches almost totally. The trees of old drainage areas were also cut as well as the tree stands in many virgin mires. The mires were fertilized with phosphorus and potassium at least once. Phosphorus was spread in winter and potassium in summer.

In most mires of Seitseminen, ditches still drain the area well enough, even if they may be covered by vegetation, mainly *Sphagna*. In the end of 1980s 79 % of the drained mires were regarded as highly productive (for terms see Aapala et al. 1995). Main part of them were in a transitional state. Real drained mire forests were few. The change from the 1930 is great. No exact data is available, but according to the old aerial photo, over 50 % of mires in Seitseminen have been very sparsely treed or open, and would have been regarded as forest land of low productivity. The poorest nonproductive sites were not drained, and their proportion has not decreased as much as that of sparsely treed mires.

The changes in ground and field layer have not been recorded. Comparing with the few virgin sites of the area, dwarf shrubs and *Eriophorum vaginatum* have benefited. Especially after fertilization *Betula nana* is growing extremely well. *Sphagna* have formed the main part of ground layer in all mires. Drainage has benefited *Pleurozium schreberi*, *Polytrichum strictum* and *P. commune* as the *Sphagna* have decreased. In most mires there are still plenty of *Sphagna* left, even if hydrophilic species may have come scarce. *Sphagnum angustifolium* gains benefit from the drainage. In driest parts lichens have spread into mire.

There seem to be several main successional directions in the drained mires in Seitseminen. If *Pinus sylvestris* is growing well, the mire is drained thoroughly all over the year. In the ground layer *Pleurozium schreberi* replaces almost totally other species. Field layer is sparse with dwarf shrubs, especially *Vaccinium uliginosum*. Also *Vaccinium myrtillus* may is present, although not abundant. There are no other real forest species, but mire species are still dominating. This stage may last very long.

In some places the tree growth is inhibited by nutrient imbalance. These places are usually covered by *Polytrichum* spp. which form extensive hummocks to the former lawns. There is a thick cover of bush-like *Betula pubescens* and poorly growing *Picea abies* but they seldom reach height of more than a few metres. In the field layer there is plenty of *Eriophorum vaginatum.* There still grow some virgin mire species like *Menyanthes trifoliata, Andromeda polifolia* and *Vaccinium oxycoccos.*

In some mires the ditches have filled up shortly after drainage. In these places the succession has been reversible, and the mire vegetation has taken over. It is not necessarily same kind of vegetation that dominated in the original mire. The hydrological conditions have usually changed so that a new kind of mire vegetation develops. These cases are so few that no accurate data is available.

4 Establishment of the national park

In the early 1960s both forests and mires in Seitseminen were almost in a natural state. The area as a whole was unique for southern Finland even at that time. Most of the area was state-owned. Intensive forestry begun then. An area of 15 km^2 in Seitseminen was proposed to be protected (Häyrinen & Ruuhijärvi 1966). The Forest and Park Service did not take this proposal into account and the forestry went on. In 1973 the State Board for Environmental Protection proposed a national park of 4 500 ha to be established in Seitseminen. The drainage of the mires had ceased but the mineral soil forestry went on. The Committee for National Parks (Tallgren et al. 1977) regarded Seitseminen still as worth establishing there a national park, even if most of the virgin forest and virgin mire had been managed. The national park was established in 1982. The size of it was 3 000 ha. In 1986 the additional area of Soljanen was united into the national park. In this area large undrained mires exist. The size of the park was 4 200 ha. Recently, some 300 ha of forests and mires was united into the national park in the northeast. The mires of this area are all drained.

5 Administration and management of the national park

Seitseminen as well most of the national parks is governed by the Forest and Park Service. The local unit responsible for it is the Park Area of Western Finland. The main persons developing and maintaining the management are regional director, manager of the park and two special planners of the Park Area. In addition there are some guides and technical staff in the national park.

The principles as well the practical activities of the national park are defined in the master plan. This is renewed from time to time. Special plans are made for some strictly limited parts, in which the management is planned in detail. The restoration plan of drained mires in Seitseminen (Heikkilä & Lindholm 1993) is this kind of a special plan.

In the new master plan of Seitseminen national park the restoration and management of biotopes is one main topic (Metsähallitus 1994). The restoration plan for mires is ready (Heikkilä & Lindholm 1993), and for mineral soil forests it is presently being done. The principles and methods of restoration of small watercourses are still needed. The main agricultural biotope in the area is Kovero museum farm. Is is restored and maintained quite effectively.

6 Restoration plan for the mires

The restoration plan is based on drainage basins, each of which is restored separately. Division was done on such level that the amount of drainage basins is 28. The statistics of the drainage basins is presented in Table 1. The plan was made using the basic topographic map (scale 1:20 000), the map of forest resources evaluation, aerial photos of different age and other available material. The area is quite large. Therefore it was not thoroughly invented in field, but numerous field studies were done to verify the evaluation of other material.

Using mainly aerial photos from years 1930, 1963 and 1991 the amount of ditches was deducted and mapped. The oldest aerial photo from the area is from 1930. At that time almost all the mires of Seitseminen were intact. So this aerial photo was used to estimate the tree stand of virgin mires in the area. It was not possible to extend the survey to the deduction of original mire site types.

The recent situation of mires was studied from the forest resources evaluation data and during field excursions. The need of restoration and suitable methods in different mires were estimated.

7 Preliminary results of the restoration

7.1 Restoration with dams - Koveronneva

The first restored area was Koveronneva mire (Fig. 1). Its area is 24 ha, and it was drained in 1970. It was fertilized with easily soluble phosporus and potassium. Koveronneva was originally an ombrotrophic bog with oligotrophy in marginal areas and around mineral soil islands. It had not changed very much in 20 years, the tree stand being poor in the 1980s. The changes in field and ground layer were mainly the disappearance of flark level species as well as enhanced growth of dwarf shrubs.

In 1987 29 dams were built into ditches of Koveronneva in an area of 9 ha (Vasander et al. 1993, Seppä et al. 1993). Additional dams have been built several times after that. The trees were cut between three ditches in an area which had been treeless before drainage (Seppä et al. 1993).

The water level has been monitored in Koveronneva from 1987 onward. It has raised only some cm after building the dams. No visible reaction can be seen in the vegetation. In an area where trees were cut numerous pine seedlings are raising. Unless dramatic change happens in near future, the restoration of Koveronneva must be regarded as unsuccessful. The main reasons are too low and narrow dams, and unfilled narrow (20 cm) ditches between ordinary ditches. All of the precipitation should be kept in the mire in order to raise the water level in a mire with a minimal catchment area. Nowadays much of the snow melting waters flow immediately away, even if the dis-charge during summer is not significant.

7.2 Filling up the ditches - Kirkkaanlamminneva

The mire Kirkkaanlamminneva is for the greatest deal a slightly minerotrophic mire, about 25 ha in size (Fig. 1). It was drained in the late 1960s. Immediately after the drainage the mire was fertilized with easily soluble phosphorus and potassium. In the eastern part of the mire there was a wet strip, through which the waters of a lake above as well as spring flood flows. In the surroundings of this treeless sedge growing strip there were oligotrophic fens in which some pines grew. The eastern margin of the mire was covered with *Betula pubescens* and *Picea abies*. In western part the tree stand was taller and thicker and the vegetation was dominated by dwarf shrubs.

By the end of 1980s the trees were growing intensively. *Pinus sylvestris* was the main species, but also *Betula pubescens* was abundant. In the marginal areas *Picea abies* was dominating. In the field layer the most abundant species were *Eriophorum vaginatum*, and *Betula nana* as well as other dwarf shrubs. Most species of the original mire were still growing in the wettest patches, for example *Eriophorum angustifolium, Carex rostrata, C. lasiocarpa* and *C. limosa*. The ground layer was very heterogeneous. In most places indifferent mosses like *Sphagnum angustifolium* dominated. In the driest part *Pleurozium schreberi* and *Polytrichum* spp. dominated. Flark level *Sphagna* had disappeared but they still grew in the virgin mire beside the nearby lake. In the western part of the mire the original hummock vegetation had not changed very much, but the lawn level had dried out.

In the summer 1992, monitoring was conducted in Kirkkaanlamminneva mire, and it was divided into main vegetation units. The ditches were filled by an excavator with the peat remaining beside the ditches from the original ditching. Most trees were cut in the winter. Branches and twigs of the trees were left in the mire. Smallest pines were removed next summer.

In the summer 1993 the water level of the mire was considerably higher than in two previous years. In the former ditches there was standing water throughout the summer. In the original wet strip water was flowing. The water was in the lawn level in most of the mire.

July and August of 1994 were abnormally hot and dry. That caused the water level in the mire to sink into the level of drained mire. From the middle of July there was no viable water and the former strip began to dry. However, the autumn was rainy and there was considerable flooding in Seitseminen. It seems that Kirkkaanlamminneva mire retained all the water after the drought.

The changes in the vegetation are difficult to monitor in this phase. The vegetation consists of innumerable patches, in which succession goes on at different speed and into different directions (see Kuusipalo & Vuorinen 1981). The strongest species all over the mire is *Eriophorum vaginatum*, which grows extremely well, is very fertile and spreads to new patches. In wet bare peat *Carex magellanica* and *Carex limosa* spread rapidly from seeds. *Rubus chamaemorus* is the dominating species in dry peat.

After the drainage *Cladina* spp. and *Cladonia* spp. had colonized driest lawns. They seem to disappear rapidly after restoration. Hummocks seem to be resistant as well to drainage as restoration. The western part of the mire was originally rather forested. As the trees were cut, the ecological conditions of the ground layer differ considerably from the virgin state. In this part the water level is still quite low. Forest species, mainly *Vaccinium vitis-idaea* and *Trientalis europaea* have benefited the situation.

It is too early to say anything definitive about the success of restoration in Kirkkaanlamminneva. Water level has raised, however, and there is visible succession taking place in the vegetation. In the future it will be seen, if the changes are to the correct direction and if they are enough to turn Kirkkaanlamminneva again to a mire ecosystem.

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EXCURSIONS TO LAKKASUO AND SIIKANEVA MIRE COMPLEXES

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1 Lakkasuo

1.1 General features of Lakkasuo mire

Lakkasuo mire (61° 47' N, 24° 18' E, 150 m a.s.l., ca. 120 ha) is an eccentric raised bog with an expanded lagg zone in its northern rear. That minerotrophic part of the mire receives considerable amounts of groundwater from the Vatiharju esker on the western rear of the mire. Due to its very diversified vegetation Lakkasuo has been a teaching site for university students in peatland forestry for decades. Numerous special mire site type demonstration areas have been established with several kilometers of wooden trails ("*Cursus paluster*") (Laine et al. 1986).

Lakkasuo is one of the principal study areas of the research project SUOSILMU (Carbon Cycling in Peatlands and Climate Change). Therefore, the excursion was focused on the demonstration of the current study projects on the different parts of the mire.

The visit started at the northwestern part of Lakkasuo. At first general information about the hydrology and vegetation of the mire was given. A restricted, narrow area of the western margin had been drained for forestry about 70 years ago. The original vegetation had been alder swamp on an approximately 1.5-m-thick peat layer. Nowadays about 1 m of peat is left and the forest is formed by a mixed spruce, birch, and alder stand (approximately 400 m^3 ha^{-1}). Both *Alnus glutinosa*, *A. incana*,and their hybrids exist.

In the eastern part of the mire about 40 ha was drained for forestry in 1961 with a forest plough. Since virgin vegetation representing different trophy levels (from ombrotrophy to mesotrophy) remain on the undrained side of the "border ditch", this provides an excellent opportunity for comparative studies on the effects of forest drainage on the carbon and nutrient balances in different site types. From the ongoing SUOSILMU projects the following ones were briefly demonstrated during the field trip:

1.2 Micrometeorological and hydrological measurements.

In order to obtain basic data for element balance studies, monitoring equipment for air-borne components have been installed together with an automatic measurement system for air and soil temperatures, radiation, and precipitation. For continuous records of the depth of the water table there are limnigraphs in both the virgin and the drained parts of the mire. The automatic measuring system has been working in the field throughout the year.

1.3 Dynamics of the "greenhouse gases".

CO_2, CH_4 and N_2O in virgin and corresponding drained mire site types are being studied along seven permanent transects from undrained to drained parts of the mire. The variation between the transects is from dry ombrotrophy to wet minerotrophy. CO_2 emission is monitored by a portable dynamic chamber system equipped with an infrared gas analyser (IRGA) from 6 - 24 permanent plots. Green plant parts have been clipped away and on half of the sites peat columns have also been isolated from the surrounding peat with plastic sheetings (Fig. 1). The isolated columns released c. 10-20 % less CO_2 than the reference spots where only the growth of green plants was restrained (Silvola et al. 1992).

In another approach, CO_2, CH_4, and N_2O fluxes are measured with a static method using 60 x 60 cm aluminium collars placed on the peat surface. Aluminium tops together with the collars form closed chambers with the living vegetation inside. A series of air samples is collected using 50-ml polypropylene syringes. Four gas samples are collected during a 30 minute measuring period. The measurements have been carried out biweekly from spring thaw to winter freezing. The concentration of CO_2 is measured in the laboratory using an IR-analyser, and the concentrations of CH_4 and
N_2O using gas chromatograph (FI-, and TC-, and EC-detectors, respectively).

The mean CO_2 emissions were greater in all drained sites than in their virgin counterparts during the period of maximum emissions in the midsummer of 1991 and were always higher in minerotrophic sites than in ombrotrophic sites. For example, in transect I (sedge fen) the mean CO_2 emission (S.D. in brackets) was 360.1 (180.9) mg CO_2 $m^{-2}h^{-1}$ for the virgin site and 570.9 (178.3) mg CO_2 $m^{-2}h^{-1}$ for the drained part. In the ombrotrophic *Sphagnum fuscum* pine bog site (transect IV) the mean hourly emissions of CO_2 were 250.5 (61.8) mg for the virgin side and 299.8 (73.0) mg for the drained side (Silvola et al. 1992).

The mean CH_4 emission from virgin and drained ombrotrophic sites was 40 mg $m^{-2}d^{-1}$ and 18 mg $m^{-2}d^{-1}$, respectively. From virgin minerotrophic site the corresponding emission was 98 mg $m^{-2}d^{-1}$, but the drained minerotrophic site consumed methane with an average uptake rate of 0.13 mg $m^{-2}d^{-1}$ (Martikainen et al. 1992).

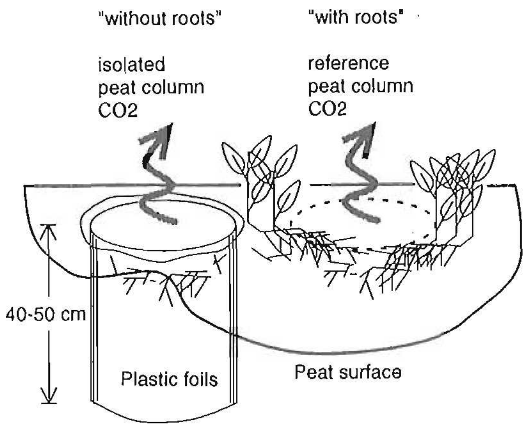

Fig. 1. Method to exhaust the root derived respiration in the field experiment (Silvola et al. 1992).

In a preliminary study carried out at Ilomantsi in eastern Finland in 1991, the virgin mire sites seemed to emit very low amounts of N_2O or to be sinks for this greenhouse gas. However, a drained mesotrophic sedge mire and a peatland in agricultural use emitted the highest mean daily fluxes of 950 ug N_2O m^{-2} d^{-1} and 5200 ug m^{-2} d^{-1}, respectively (Martikainen et al. 1992). Also, in Lakkasuo the drained parts of transects I (sedge fen) and 0 (mesotrophic flark fen) have been noted to emit N_20 in small quantities (Dr. Pertti Martikainen, pers. comm. January 1993).

1.4 Fine root production on peatlands.

Annual fine root production is studied in two drained *Pinus sylvestris* stands: one from an originally treeless sedge fen (transect I) and one from a sedge pine fen site (transect II). Soil samples from the same sample plots are analysed for living and dead fine roots (diam. < 10 mm) and for the rate of decomposition from samples obtained over a period of three years from the depths of 0-10 cm, 10-20 cm, and 20-30 cm. Total fine root biomass (397 g m^{-2}) and total root production during May-September 1991 (178 g m^{-2}) at the afforested and fertilized sedge fen (transect I) were lower than the corresponding figures for the drained sedge pine fen (transect II); biomass 529 g m^{-2} and annual production 242 g m^{-2}. Almost half of the fine root biomass was renewed during the summer (Finér et al. 1992).

1.5. The role of leaching in the material balance of peatlands.

Lakkasuo was chosen for the main study site of this subproject. Four catchments in Lakkasuo are monitored: a bog and a fen, both in natural state and drained for forestry 30 years ago (Fig. 2). The undrained bog and fen catchments are gauged, but the drained sites (only two hectares in size) utilize hydrological data from a nearby gauged, drained mire catchment. The main goals of the study are to determine:

- the role of leaching and retention in the long-term material balance of mires
- the primary regulators in the leaching process
- the effect of climatic change on the leaching rates from peatlands

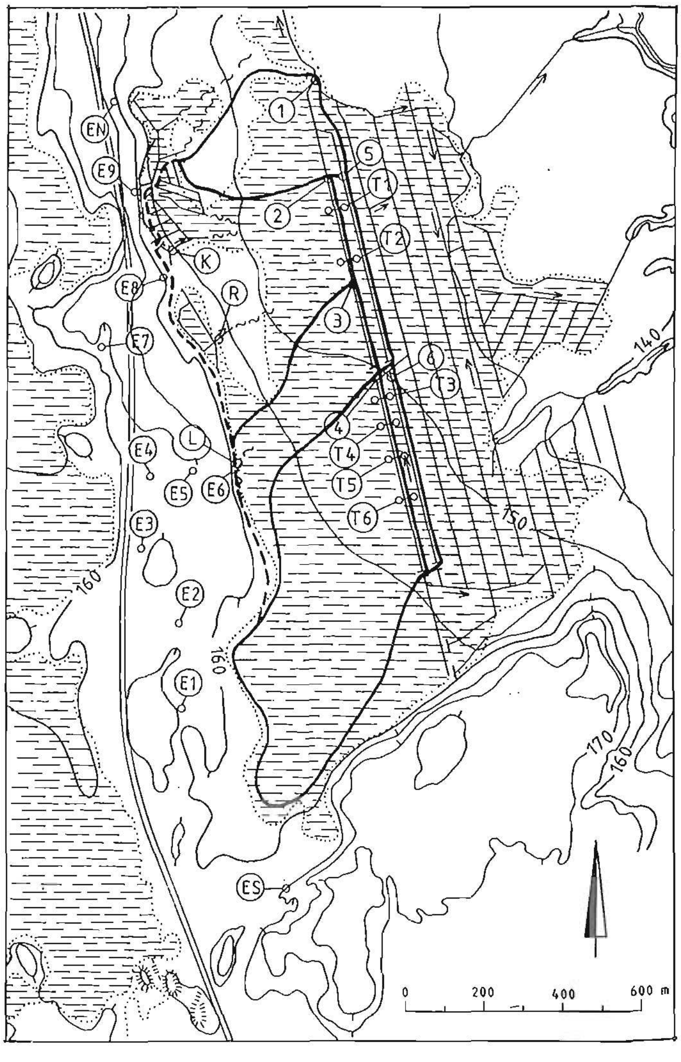

Fig. 2. The monitoring sites and catchment areas at Lakkasuo. 1-6 – runoff water quality. T1-T6 – transects (transect no. 0 in the north is not marked). K,R,L – inlets for water quality monitoring. E1-E9, EN, ES – ground water level monitoring wells in the esker. (Sallantaus 1992).

The runoff of ombrotrophic waters are recorded continuously. The water samples are collected weekly or biweekly and analyzed for all the charged and uncharged components in addition to some important plant micronutrients.

Some results obtained by Sallantaus (1992) were briefly demonstrated on a measuring gauge close to transect III. Leaching of organic carbon from the catchments in the relatively wet study period (runoff 414 mm from the undrained bog) ranged from 8.0 to 16.6 g m^{-2}. The outputs from the undrained catchments were lower when compared with the drained ones (8.0 *vs* 14.1 g m^{-2} for fen and 12.4 *vs* 16.6 g m^{-2} for bog areas, respectively). All the catchments retained amounts of the total N and sulphate provided by deposition or groundwater very effectively (65-80 % and 52-72 %, respectively). The net output rates of all the elements except H+ were greater from drained catchments than the virgin ones.

1.6 Accumulation of carbon in peat layers, with special emphasis on the past few hundred years.

Some of the methods used and preliminary results obtained by this subproject were demonstrated on transects III and IV. Peat columns with known bulk density were dated by means of the "pine method" (determining the age of root collars of pines buried in peat) up to about 100 years and/or by means of "moss increment dating" up to some 50 years. Dating of older (147 and 215 years) layers using fire horizons at a depth of 13 - 58 cm in peat was done by dendrochronological dating of fire scars encountered in numerous pine stumps in the study area. A local master curve for upland pines was constructed and a cross-dating of the mire pine stumps , albeit difficult, was successful (for details, see Alm et al. 1992)

A third fire horizon interspersing the peat strata about 100 cm from the present surface was dated at about 1 040 B.P. by means of high resolution ^{14}C dating and the "wiggle matching" approach (about 20 AMS radiocarbon datings from cleaned stems of *Sphagnum).* This was done at one site from transect IV. These fire horizons enabled a statistical comparison of the rate of apparent carbon accumulation (for the terms, see Tolonen et al 1992a) for periods 215 and 1 040 B.P. in virgin site and in drained tall shrub pine bog that was ditched 30 years ago (Tolonen et al. 1992b).

The true (actual) rate of carbon accumulation, however, is smaller. This is because the slow decay in deeper anoxic layers contributes to an additional loss of carbon through gas emissions. One approach to estimate the true net accumulation of carbon is to use peat accumulation models for the whole peat strata with numerous dated levels (Clymo 1984, Tolonen et al. 1992a).

1.7 Differences in response of two *Sphagnum* species to elevated CO_2 and nitrogen input.

A field trial at the southwestern part of Lakkasuo was demonstrated where *Sphagnum fuscum* and *S. angustifolium* were exposed to a gradually elevated artificial load of nitrogen. By monitoring the areal cover and the height increment of these two species we hoped to answer to the question above as far as nitrogen is concerned. The laboratory experiments indicated clear responses of both *Sphagnum* species to elevated nitrogen deposition. However, *S. angustifolium* was more tolerant of nitrogen (Jauhiainen et al. 1992). There was no clear response to the elevated CO_2 level although the shoot density of *S. fuscum* increased with increased ambient CO_2. Also, the timing of growth was different in the highest ambient CO_2(Jauhiainen et al 1994).

2 Siikaneva

During the last day of the symposium an excursion was made to a large mire complex named Siikaneva (61°41' N, 24° 06' E, 160-170 m a.s.l.), about 10 km northwest of Hyytiälä Forestry Station. Siikaneva consists of several eccentric raised bogs and wide treeless fen parts (aapa mires) which together form a diversified mire complex. The total area of this complex (including the mineral soil islands) is 1 560 ha, and its main part is now protected under a different status. In 1976 several private owners voluntarily established a nature reserve of 357 ha in the western part of Siikaneva, confirmed by the law of nature conservation. The conservation judgement was made by the provincial government. In 1988, the state-owned part (699 ha) was established as a mire conservation area. This conservation judgement was made by the Finnish parliament (Law 851/88). The master plan for this part is just now being worked out in the National Board of Forestry.

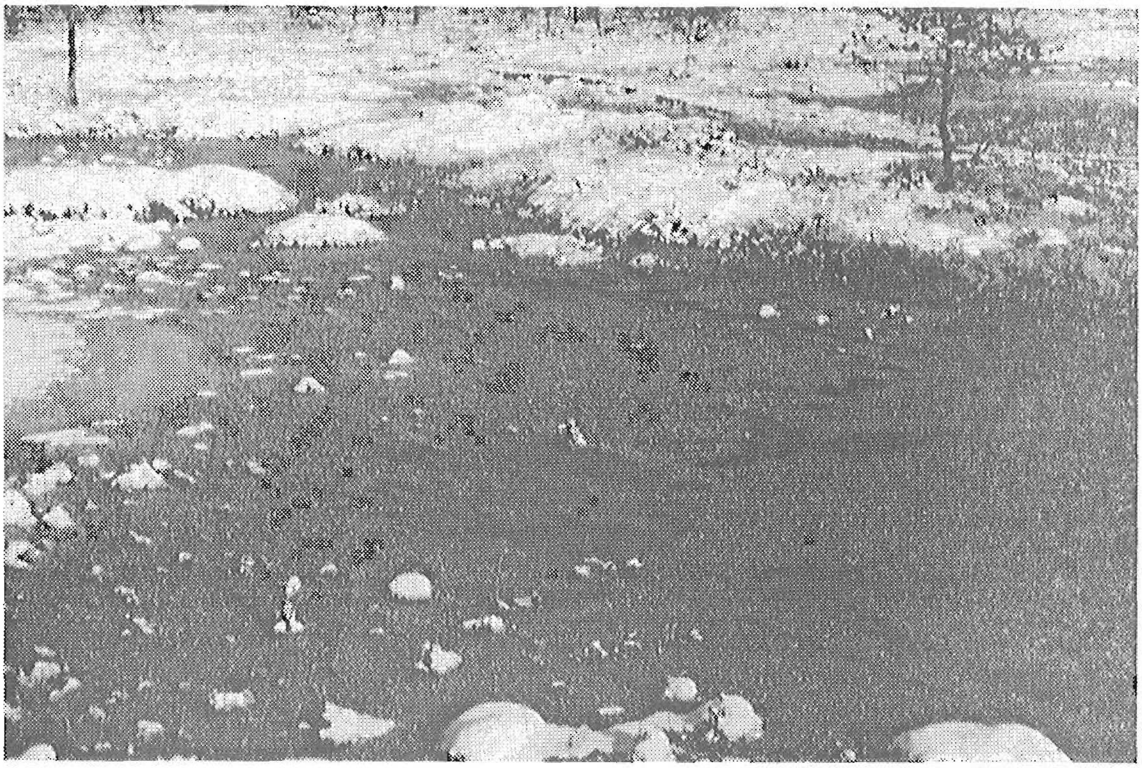

Fig. 3. The open areas in the mud bottom pools gave evidence of the gas emissions from the peat (Foto: H. Vasander).

Since a detailed guide about the general outlines of the vegetation, hydrology, water chemistry, geology, and avifauna of Siikaneva (Tolonen et al. 1979) was distributed to the excursion participants, this report is restricted to a brief description of the trip and discussions during it.

At first, a general overview of the whole area was taken in the former fire protection tower of Moskulanmäki hilltop on the northeastern edge of the complex.

The landscape has preserved its virgin wilderness nature; a bit surprising when thinking its location in southern Finland. Wide glaciofluvial gravel and sand areas prevail in the north and west, while till-covered rocky hills border the mire basin in the eastern and southern side. Correspondingly, the former areas are mainly dominated by pine forests whereas spruce and mixed forests with more luxurious vegetation both on upland soils and on mires characterize the latter, more fertile soils.

A six kilometer long walk was started from the northeastern margin of the mire complex, not far from Kilpilampi lakes. Due to the season (late fall) and the preceeding rainy period the relatively wide eastern lagg was covered by water. For most of the summer time, however, it is dry with *Juncus filiformis* being the most abundant plant species. The peat layer on such places is only a few decimeters thick, highly decomposed, and mixed with mineral material transported by flooding. According to stratigraphical studies, the expansion of the mire in the eastern part of the complex *via* paludification has been weak after the general spread of *Picea* into the area some 5 000 years ago (Lukkala 1933).

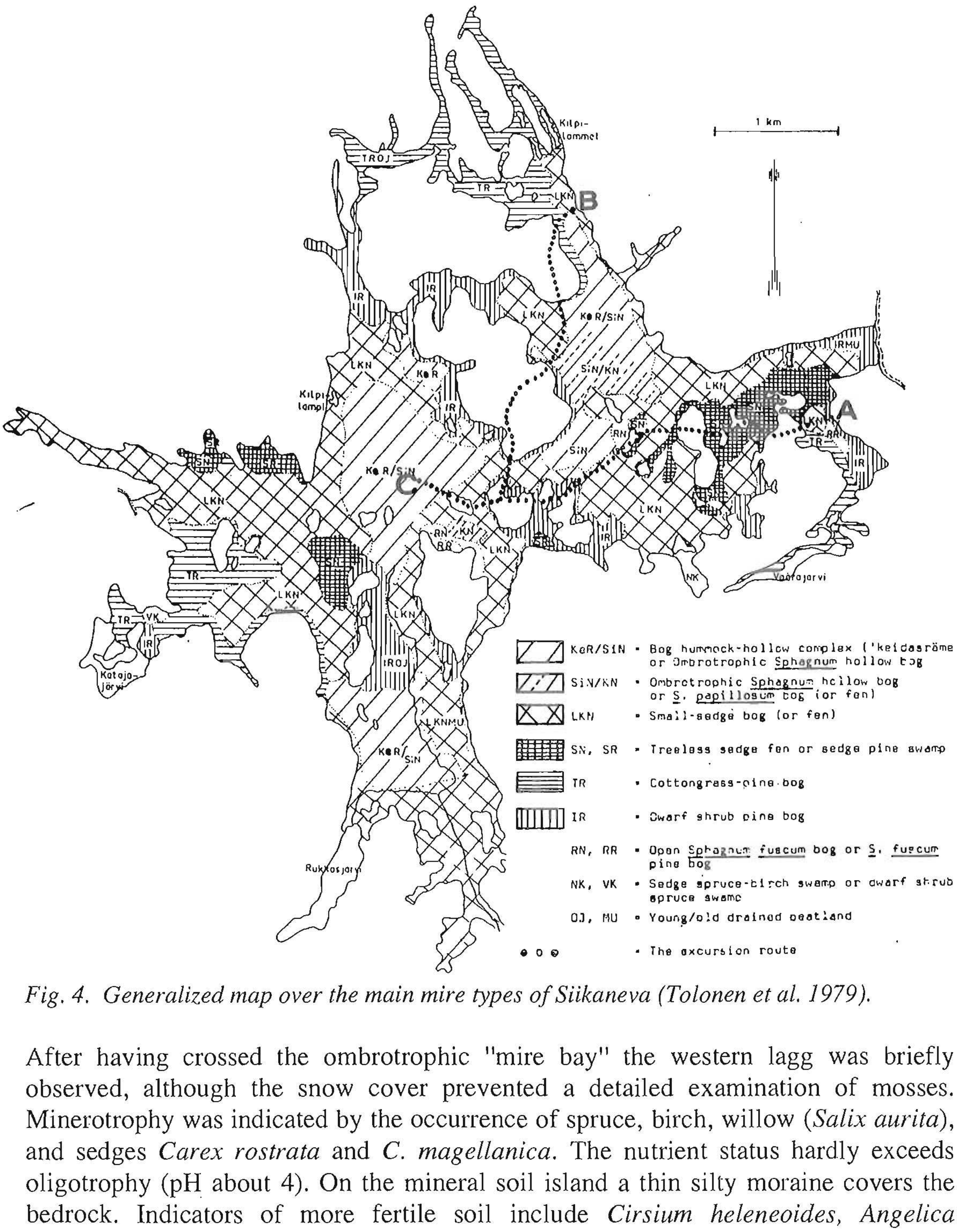

Fig. 4. Generalized map over the main mire types of Siikaneva (Tolonen et al. 1979).

After having crossed the ombrotrophic "mire bay" the western lagg was briefly observed, although the snow cover prevented a detailed examination of mosses. Minerotrophy was indicated by the occurrence of spruce, birch, willow (*Salix aurita*), and sedges *Carex rostrata* and *C. magellanica*. The nutrient status hardly exceeds oligotrophy (pH about 4). On the mineral soil island a thin silty moraine covers the bedrock. Indicators of more fertile soil include *Cirsium heleneoides, Angelica silvestris, Lathyrus vernus, Tilia cordata,* and *Viburnum opulus*.

The next lagg zone on the western side of the first mineral soil island crossed is narrow and quite dry due to smaller amounts of water (restricted catchment area, etc.). On the ombrotrophic part, many mud bottom hollows (Torfschlammschlenken) occur with almost no vegetation. The active bubbling of mire gas(es), probably methane, was evidenced by the small unfrozen holes in the ice cover of shallow pools (Fig. 3).

The occurence of *Sphagnum papillosum* in this ombrotrophic part was discussed by the participants. There are no indicators of minerotrophy among the vascular plants and mosses, and it has been reported that *S. papillosum* can grow on domed ombrotrophic bogs in western Finland (Aartolahti 1965). Our site is a part of an eccentric bog. We have no chemical analyses nor studies on the algal flora of the site. The mire is 3 - 4 m deep, and upon visual inspection the peat is ombrogenous for the main part. Three alternative explanations were discussed in the field.

1. The site is slightly minerotrophic, receiving an extra nutrient supply from the north (see Fig.4) due to the rain during the spring floods. Detailed levelling and study of the hydrology of the area would be needed in order to confirm this hypothesis.

2. The nutrient status of mud bottom surfaces is higher than in other ombrotrophic communities - just enough for *S. papillosum* in this ecological area (Ökoareal). Tolonen and Hosiaisluoma (1978) have found that both pH and calcium were higher in mud bottom surfaces than in moss-covered hollows. Perhaps the mineralization and/or fixation of nitrogen (by algae) is higher in mud bottom communities compared to other surfaces, as well.

3. *S. papillosum* is a relic from the former minerotrophic stage representing a kind of minerotrophic window in the ombrotrohic area. Stratigraphical studies would be needed to confirm this hypothesis.

Before and during the field coffee break the well-patterned hummock - hollow complex on the eccentric bog part of western Siikaneva was observed from a rocky hilltop. The role of biological and physical factors in the origin of hummocks on the patterned peatlands was briefly discussed. The importance of different factors probably varies from one region to another, and thus any general explanations are hard to come by. The retardation of peat accumulation in depressions, for several reasons, certainly explains a lot of the developmental stages of hollows and pools. The mechanisms of induction, i.e. the very first stages of hummock formation, is however still open for discussion.

Although Siikaneva has a very long history as a peatland with the oldest peat layers being dated to 8 870 ± 150 B.P., several sites were encountered during the excursion where the developmental process towards a typical raised bog topography and morpohology apparently was a relatively recent feature. Ombrotrophication of treeless low-sedge fens was observed on many sites; *Sphagnum magellanicum* with abundant *Andromeda polifolia* showed that succession.

A roundish spring like water "hole" (about 1 m in diameter) located at the topographical boundary between the marginal slope and the dome in the eastern part of the complex (about 1,5 km west of Point A in Fig 4) was visited during the trip (Fig. 5). This site has been observed to be unfrozen through the coldest winters unlike all the other hollows and pools. Surprisingly, the depression and its surroundings lack all the minerotrophic species that usually characterize springs. The nature and origin of this hole inspired an intensive discussion in the field. Dr. Elon S. Verry (US Forest Service, North Central Forest Experiment Station, Grand Rapids, Minnesota, pers.

comm. January 1993) has suggested that this hole could indeed be a spring receiving both groundwater from the mineral soil islands by means of subsurface flow and peat waters from a wide catchment. Due to the extremely low mineral nutrient content of the parent rock and of the minerals in the glacial drift, the minerotrophic waters of Siikaneva mire differ from ombrotrophic ones only in a few properties such as Mg, Si, and Fe levels (Tolonen et al. 1979). A way to have a (partial) answer to the problem would be to perform chemical analyses on water from the hole. Hydrological monitoring of the water movements would be needed, as well.

Fig. 5. A small unfrozen "hole" in Siikaneva was visited during the field excursion. This site aroused a long discussion. Foto: H. Vasander.

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Finnish and Karelian ministeries of environment ratified a contract on cooperation in mire conservation research in 1992. The aim of the cooperation is to improve the classification and conservation of mires in the biogeographically uniform area of Eastern Fennoscandia, and to develop and unify the research methods. This publication presents results of this work in a collection of articles dealing with classification and conservation of mires in Finland and Karelia, based on presentations in a Finnish-Karelian symposium. Topics included in this volume cover paludification processes, stratigraphy of fens, development of the nutrient status of mires, growth of peat mosses, carbon balance and utilization of mires, present vegetation of protected mires, threatened mire plants, degree of drainage of mires in the raised bog zone, additional plans for mire conservation, and restoration of drained mires.

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